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WHO CHRONICLE

VOL. 13, No. 1 - JANUARY 1959

The Problem of Bilharziasis

Bilharziasis as a Man-Made Disease

Bilharziasis in the Laboratory

Molluscicides in the Control of Bilharziasis

The Leyte Bilharziasis Project

Notes and News

Review of WHO Publications

WORLD HEALTH ORGANIZATION
PALAIS DES NATIONS
GENEVA

The World Health Organization (WHO) is one of the specialized agencies of the United Nations. Through this organization, which came into being in 1948, the public health and medical professions of more than 80 countries exchange their knowledge and experience, and collaborate in an effort to achieve the highest possible level of health throughout the world. WHO is not concerned with problems which individual countries or territories can solve with their own resources. It deals, rather, with problems which can only be satisfactorily solved through the co-operation of all, or certain groups of, countries—the eradication of diseases such as malaria, the control of cholera, plague, yellow fever, smallpox and rickettsiosis. Progress towards better health throughout the world also demands international co-operation in many other activities : for example, setting up standards for biological substances, for insecticides and insecticide spraying equipment ; compiling an international pharmacopoeia ; drawing up international sanitary regulations ; revising the international lists of diseases and causes of death ; assembling and disseminating epidemiological information ; recommending non-proprietary names for drugs ; and promoting the exchange of scientific knowledge. In many parts of the world, there is need for improvement in maternal and child health, nutrition, nursing, mental health, environmental sanitation, public health administration, professional education and training, and health education of the public. Thus a very large share of the Organization's resources is devoted to giving assistance and advice in these fields to countries and territories whose health services are in an early state of development and which are therefore weak points in the common front against disease.

- ***WHO Chronicle***

  (formerly *Chronicle of the World Health Organization*) published by WHO for the medical and public health professions, provides a monthly record of the principal health activities undertaken in various countries with WHO assistance. It also contains summaries and detailed accounts of the other publications issued by the Organization.
  The Chronicle is published in English, French, Spanish, Russian and Chinese.

- ***Bulletin of the World Health Organization***

  contains technical articles, in English or French, contributed by physicians and scientists engaged in public health work. It appears monthly and each issue runs to about 200 pages.

- ***World Health***

  an illustrated magazine for the general public, aims at giving an idea of WHO activities throughout the world and at showing some of the more striking aspects of public health work.
  This publication appears every two months in English, French, Spanish and Portuguese.

Other WHO publications: the *Technical Report Series*, the *Monograph Series*, the *Epidemiological and Vital Statistics Report*, the *International Digest of Health Legislation*, etc., are described in a catalogue which can be supplied free of charge on request.

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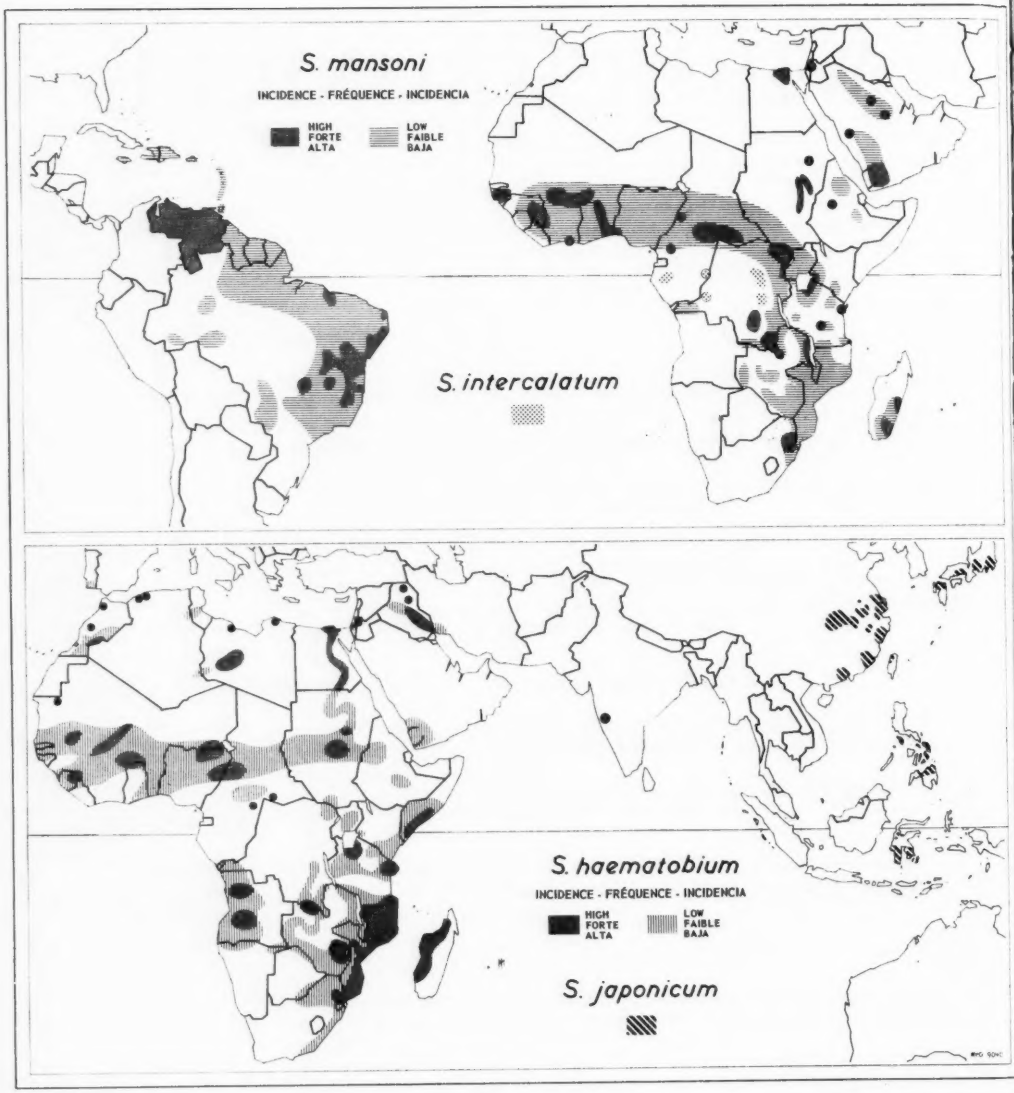
WORLD HEALTH ORGANIZATION

WORLD DISTRIBUTION OF BILHARZIASIS



*Bilharziasis, widely spread through Africa, the Eastern Mediterranean, some countries of Latin America, and the Western Pacific, is now recognized as being second in importance only to malaria as a parasitic disease. Since its inception, WHO has sought to find answers to the many complicated problems in different fields that are raised by attempts to control the disease. This issue of the Chronicle describes some of these problems, and outlines the work that has been and is being done by WHO. A lengthy section is devoted to an account of the WHO bilharziasis project in the Philippines, which illustrates admirably the difficulties encountered, and the painstaking and time-consuming studies required as a preliminary to measures of control.**

NATURE AND EXTENT OF THE PROBLEM OF BILHARZIASIS

Introduction

For thousands of years a chronic endemic disease, characterized by blood in the urine and by various bladder troubles, has been known to exist in Egypt and elsewhere. The eggs of the parasite which causes the disease have been discovered in the kidneys of mummies of the Twentieth Dynasty (1250-1000 B.C.), and a clinical account of what appears to be the disease has been found in a papyrus. Its symptoms have been described in Babylonian inscriptions, and in mediaeval medical literature. It was only in 1851, however, that Bilharz, then an assistant Professor at the Cairo School of Medicine, found the causative agent in the mesenteric vein during a post-mortem examination, and identified it as a fluke. This parasitic worm bears the generic name of *Schistosoma*, and the disease it causes in man is called bilharziasis.[1]

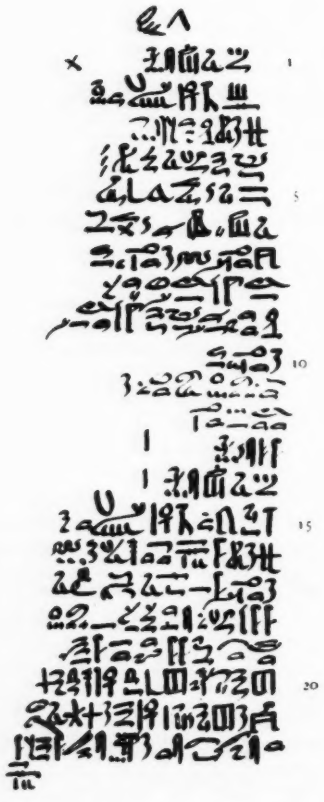
The pathology of the disease was largely elucidated in the nineteenth century, but it was not until the twentieth that the life cycle of the parasite was traced, although both Harley and Cobbold had expressed the view in 1864 that a mollusc was the intermediate host.[2] In 1902 Manson postulated the existence of a second species of *Schistosoma*, and when this was later conclusively demonstrated it was called *S. mansoni* after him. Yet a third species causing disease in man was identified in Japan, and called *S. japonicum*. Fujinama and Nakamura identified the intermediate host of *S. japonicum* in the years 1907-1910, and in 1915 Leiper identified the intermediate hosts of *S. haematobium* and *S. mansoni* in Egypt. In 1923 Miyairi and Suzuki succeeded in infecting snails with the miracidia, the free-living larvae hatched from the eggs of the parasite, and in the same year Leiper and Atkinson traced the further development of the parasite in the liver of infected snails, and demonstrated the penetration of the skin of mice by the immature forms escaping from the snails and their growth to maturity in the mesenteric veins of mice or hamsters. In 1925 Leiper observed the development of miracidia of *S. haematobium* in the freshwater snail *Bulinus*, and in 1926 that of miracidia of *S. mansoni* in another genus. He also demonstrated that the immature forms leaving the snails in each case differed in their minute anatomy, so that the species were different.

* The articles on bilharziasis contained in this issue will be published in booklet form under the title *International work in bilharziasis, 1948-1958*. This publication will be the fourth in a series of studies devoted to particular fields of WHO activity. The previous publications in the series were: *Treponematoses : a world problem*, by T. Guthe & R. R. Willcox (1954); *Malaria : a world problem*, by E. J. Pampana & P. F. Russell (1955); and *Disease control and international travel*, by H. S. Gear & Z. Deutschman (1956).

[1] By a decision of the International Commission on Zoological Nomenclature (*Opinions and declarations of zoological nomenclature*, 1954, Opinion 226 (Supplement to Opinion 77), vol. 4, pp. 176-200), the generic name of the group to which the human blood flukes belong is *Schistosoma* Weinland, 1858, and not *Bilharzia* Meckel von Hemsbach, 1856, nor yet *Bilharzia* Cobbold, 1859; but the same body recommended that the term "bilharziasis" should continue to be used for the diseases which they cause in man.

[2] Harley, J. (1864) *Med.-chir. Trans.*, 47, 55; Cobbold, T. S. (1864) *Entozoa*, London

Further investigations have shown that other schistosomes can cause disease, and that each species consists of various strains.



A portion of the Papyrus Ebers, an Egyptian papyrus of about 1500 B.C. in the US Library of Congress. It contains a remedy " to kill worms in the body that have been caused by the AAA disease ", which is thought by some authorities to be bilharziasis.

Essentially, however, the most important in human disease are the three already mentioned: *S. haematobium*, the main cause of the urinary type of bilharziasis; and *S. mansoni* and *S. japonicum*, the main causes of the intestinal type of the disease.

Distribution and importance

It is estimated that some 150 million human beings throughout the world suffer at present from bilharziasis, the disease being widely distributed through Africa, the Eastern Mediterranean, China, Japan, the Philippines, the Celebes, and parts of South America. Some approximate figures collected by various experts are given in the accompanying table. A full survey of the extent of the disease has not yet been made. The methods of investigation ordinarily used in the surveys that have been carried out only give minimum figures, for repeated examination of subjects previously diagnosed as negative brings the total number of identified cases up to a figure considerably higher than the original. Moreover, it is difficult to isolate the part played by bilharziasis alone in the morbidity of a population which suffers from other parasites and infections concurrently, as well as from nutritional deficiencies. Because of its wide distribution and the large number of people affected, bilharziasis is now beginning to be recognized as second only to malaria in importance as a parasitic disease. It presents one of the major public health problems still to be solved in many tropical and sub-tropical regions.

Normally, bilharziasis neither kills nor incapacitates completely, although post-mortem study leads to the conclusion that the damage it does to the bladder, intestines, liver, lungs, and other organs far exceeds what would be suspected on clinical and parasitological grounds. But even when it is not associated with other infections, as it often is, it affects the physical and mental development of children and greatly diminishes the strength and productive power of adults, gradually sapping their resistance and making them easy prey for other infections. In some areas the impaired productivity of infected individuals is not obvious because they unconsciously adapt their working output to their reduced strength, so that the damage done by the disease is disguised until they are required to put out more physical effort, as they did during the war or do in the execution of public works or

ESTIMATED DISTRIBUTION OF BILHARZIASIS IN VARIOUS PARTS OF THE WORLD

	Population infected	Authorities
Egypt	12 000 000 — *S. haematobium* *S. mansoni*	N. Ayad [a]
West and Central Africa (including Belgian Congo)	7 000 000 — *S. haematobium*	J. Gaud [b]
West Africa	1 350 000 — *S. mansoni*	J. Gaud [b]
Madagascar	100 000 — *S. haematobium* 200 000 — *S. mansoni*	J. Gaud [c]
Sudan — Gezira	200 000 — *S. haematobium*	N. Ayad [a]
Belgian Congo	722 000 — *S. mansoni*	J. Gaud [b]
China	32 777 000 — *S. japonicum*	W. Wright [d]
Japan	174 000 — *S. japonicum*	G. W. Hunter [d]
Philippines	250 000 — *S. japonicum*	T. Pesigan [d]
Brazil	4 000 000 — *S. mansoni*	Nat. Dept. of Health
Venezuela	70 000 — *S. mansoni*	J. Jové [e]

[a] *Bull. Wld Hlth Org.*, 1956, **14**, 1
[b] *Bull. Wld Hlth Org.*, 1955, **13**, 209
[c] *Bull. Wld Hlth Org.*, 1955, **13**, 259
[d] *Bull. Wld Hlth Org.*, 1950, **2**, 581
[e] *Bull. Wld Hlth Org.* 1956, **14**, 617

irrigation projects. The state of balance often achieved between the parasite and the human host then breaks down, and subjective as well as objective symptoms of bilharziasis suddenly appear. This state of balance is another of the reasons why the true extent of the disease is still only approximately known; in the case of *S. haematobium*, for example, some degree of haematuria and bladder or kidney pain is so common in endemic areas that it is regarded as normal, and no one thinks of going for treatment or even of reporting such everyday symptoms to a doctor. In one section of the European population of southern Africa, indeed, haematuria in boys has been regarded as a normal condition associated with puberty.[3]

Attempts have been made to estimate the economic loss due to bilharziasis in certain areas. The WHO Leyte bilharziasis project in the Philippines [4] calculated the annual loss for 125 000 infected persons at $1 350 000 (the minimum daily wage in this country being $2.00). The total medical expenditure, worked out for 100 000 persons who showed definite symptoms, was $5 282 500. In Japan the economic loss, plus the cost of treatment for an area of 90 square miles, was reckoned at $3 million per year, and the loss for the Isle of Kyushu at $2 500 000. In Egypt, where the disease is hyperendemic, the reduction in total economic productivity is estimated to be some 30%, and the financial loss $57 million annually. Medical treatment for 1700 American soldiers infected in Leyte during the war cost $3 million, and it was calculated that 300 000 working-days were lost. In *S. japonicum* infections the working ability of patients is reported to be reduced by 15-18% in mild cases, by 50-57% in moderate cases, and by 72-80% in severe cases.

Most of the areas where bilharziasis is found are to a greater or lesser extent underdeveloped, and the disease is found mainly among the agricultural population. Another characteristic of these areas is that irrigation is practised in one form or another, by

[3] *Bull. Wld Hlth Org.*, 1956, **15**, 261
[4] See page 39.

streams, channels from rivers, the drainage of swamps, or distributaries from canals. The presence of water of suitable velocity and temperature and of adequate vegetation and organic food is a prerequisite for the establishment of the snails which are the intermediate hosts of the schistosomes.

Bilharziasis is most commonly found among the less prosperous inhabitants of these under-developed areas. Since the war there have been steadily increasing efforts to raise standards of living in these areas and among these inhabitants, and great technical assistance projects are being planned or carried out to that effect. Part of this attempt to provide better living conditions consists in improving water-supplies, increasing the amount of irrigation by means of reservoirs and canals, and making irrigation perennial where previously it was seasonal. One incidental, and unforeseen, result of these schemes is to provide ideal conditions for an extension in the range of the intermediate hosts of the bilharziasis parasite; and this is in fact what is happening in a number of places. Bilharziasis is accordingly increasing in proportion as new irrigation projects create a greater number of suitable habitats for vector snails; [5] and if the projects also bring together, as they often do, infected and non-infected persons, it does not take long for the non-infected to become infected. In the Gezira area of the Sudan, for example, *S. haematobium* infection was seen only sporadically before the introduction of irrigation. A survey afterwards showed that the infection rate for children had reached as much as 80% in some places.

The situation in Egypt has been described by the Chairman of WHO's first advisory group on bilharziasis:

> " With no rainfall, Egypt depends on the Nile for its life. There are at present 6 000 000 acres under cultivation. The development of irrigation schemes during the past century has resulted in the prosperity of the country and the increase of the population to 1400 people per square mile. In ancient times a system of dykes divided the fields into large basins which were flooded from September to October, when the flood water was drained back to the river. Under this system one single crop could be raised. The modern system of perennial irrigation ensures a water supply all the year round, and an unbroken succession of crops. It entails storage of water in huge reservoirs and the digging of large distributary canals which ramify all over the country. A similar drainage system is now under development to prevent the water-logging of the soil.
>
> " Upper Egypt, from Asswan to Assint, with the exception of small districts, is still under basin irrigation. The remaining parts of the valley and the Delta are under perennial irrigation. The permanent canals furnish an ideal environment for the breeding of the snail vectors of bilharziasis, while their proximity to the villages exposes them to pollution and makes them a source of infection. Thus perennial irrigation is responsible for a high incidence of bilharziasis in areas where it has been established. Future change from basin to perennial irrigation will increase the spread of bilharziasis, unless control measures go hand in hand with the development of the new irrigation schemes." [6]

Life cycle of the bilharziasis parasite

The problem of the control of bilharziasis will be made clearer by a brief recapitulation of the life cycle of the schistosomes which cause the disease. The adult forms mature in the blood of a human being (or of another host), and the eggs are laid in the vesical plexus or the mesenteric plexus round the colon; the adult worms are capable of living for 20-30 years, the female producing eggs continuously. The eggs escape through the bladder or intestinal wall into the urine or faeces, and on contact with water hatch, producing free-swimming larval forms, called miracidia, which must find suitable snail hosts within a certain time or perish. When a miracidium finds a suitable intermediate host it penetrates the skin and establishes itself in the snail, passing through several generations and multiplying to form further free-living larval forms called cercariae. These emerge from the snail and swim about until they find a human being. They then bore through the unbroken skin (or through the

[5] Joint OIHP/WHO Study-Group on Bilharziasis in Africa (1950) *Report on the first session*, p. 14 (*Wld Hlth Org. techn. Rep. Ser.*, No. 17)

[6] Abdel Azim, M. (1948) *Problems in the control of schistosomiasis in Egypt.* In: *Proceedings of the Fourth International Congresses on Tropical Medicine and Malaria, 1948*, Washington, D.C., vol. 2, p. 1013

buccal mucosa if the water is swallowed), make their way to the liver, mature, and mate. The two sexes then make their way to the terminal blood vessels near the bladder or colon, where the eggs are laid and the cycle begins over again.

The problem of control

Theoretically, control over bilharziasis can be achieved by breaking the life cycle of the parasite at any one of a number of points. The adult worms could be killed in their human host. The eggs could be prevented from reaching water. The snail vectors could be eliminated. Human beings could refrain from drinking or entering contaminated water. In practice, however, the problem is enormously complicated, as is obvious from the mere fact that the disease, far from being brought under control, is actually on the increase.

To begin with, the drugs most commonly used to kill the adult worms in the human host are toxic, unpleasant, whether given by injection or orally, and they involve a lengthy course of treatment, during which little or no work should be done. The result is that the patients—who are usually ignorant and illiterate—often fail to continue treatment long enough to receive the full dosage. In Egypt, for example, where treatment has been carried out on a large scale for many years, the number receiving treatment in any one year is only about 5 % of the total number of infected persons in the country, and the treatment given is generally never completed. The reservoir of infection is accordingly hardly affected, and often the parasites are not killed because not enough drugs have been taken. Moreover, even if the parasites have been killed, reinfection rapidly occurs if the patient enters contaminated water, for the drugs used in treatment, when eliminated in the body, leave the patient as subject to infection as before. The treatment must then be repeated after an interval, or, alternatively, the patient must be shielded from further infection. If, indeed, he is subjected to a fresh and severe infection, effective treatment may actually be disadvantageous to him, by rendering him more vulnerable.

Another approach to the problem is along the lines of improved sanitation. If the eggs do not reach water they cannot hatch. Consequently, if people are educated to urinate and defecate away from water, and to refrain from drinking or entering contaminated water, the life cycle of the parasite will be interrupted and the disease brought under control. To achieve this end, habits dating back for thousands of years must be broken. Human excreta are widely used as a fertilizer in the endemic areas, and there would be great opposition to any scheme to stop this traditional practice unless a substitute were provided. A religious requirement in some Moslem countries is that the anal and urethral orifices be washed with water after urination and defecation, so that uncontaminated water would have to be made available and the water used prevented from conveying infection. All the countries where bilharziasis is prevalent are hot, and in many the inhabitants, especially the children, keep themselves cool and clean by constant bathing in pools, streams and canals, which frequently are infected with snail vectors. The only way to prevent this would be to furnish bathing-pools of clean chlorinated water.

The villages where the disease is rife are usually without sanitation, and the cost of providing it on the scale needed is at present prohibitive in all but a few places. Moreover, in irrigated agricultural areas such as the Nile Delta, even if the peasant is provided in his village with pure water and sanitary latrines, he would only be able to use them to a limited extent, since he spends the whole day away from the village in his fields, under permanent temptation to use the water for all purposes. Where work takes peasants into fields full of contaminated water—certain rice-fields in the Philippines, for example—they could protect themselves by wearing suitable clothing. But protective clothing is expensive, and burdensome to wear in a hot climate.

The problem of insanitary habits is far from being a simple one, therefore, and is

closely bound up with problems of levels of living, traditional customs, and economic and social development in each of the countries concerned.

The other main line of attack on the schistosome has as its objective the elimination of the snail vector. Here too the problems are manifold. The natural history and ecology of the snails are insufficiently known. There is information about the effect on them of light, heat, desiccation, the pH, turbidity and rate of flow of the water in which they live, and about the vegetation they are attracted to, their predators, the diseases from which they suffer, and the chemicals which kill them; but more knowledge is required. The classification of these snails has only recently been established, and the exact number of species which can serve as intermediate hosts is not yet known. The optimum time and conditions for the destruction of each species are not certainly known, and, even if they were, methods of preventing reinfestation from other sources have yet to be perfected.

Nor are these the only problems that arise. Although reservoir hosts appear to play little part in the maintenance of *S. mansoni* infections, little is known on the subject and it is now thought that their importance in this respect may have been underestimated. A wide range of wild and domestic animals act as reservoir hosts for *S. japonicum*. Accordingly, in any attempt to control bilharziasis by effective disposal of human excreta, success will depend on a whole series of variables: the incidence of the disease in man, its incidence in snails and in reservoir hosts, the relative importance of the various hosts, and the degree to which disposal is effective.

Another problem is that of immunity to the disease. As far as is known, practically all human beings are susceptible to the disease, regardless of race, age, and sex. But in isolated instances infections not renewed by further exposures tend to disappear spontaneously in a few years, as the worms gradually die out. Their life span, though it may extend to twenty years or more, does not generally exceed five. This may lead to a gradual disappearance of the disease in areas where the streams are no longer infested by vector snails, and is clearly of great epidemiological importance. Nor is anything known about the reasons for the variability in the virulence of the disease in different localities.

Underlying all these problems is the question of the economic cost of control of the disease. Those who suffer from it are almost invariably the poor, the ignorant and the uneducated; in fact, those who are most attached to traditional methods, most unwilling to adopt any changes in their mode of life, and most opposed to taking positive action on their own behalf, unless the goal is an immediate and tangible one. The debilitating effect of bilharziasis, too, tends to confirm them in their apathy and distrust of innovation by making them averse to undue physical effort; and they live in warm climates conducive to reduced exertion, and suffer from other weakening diseases and deficiencies. The effort of educating them and inducing them to take positive measures to improve their health and adopt more hygienic habits calls for immense expenditure of time and patience, and thus for an adequate supply of staff and for adequate funds. And there is also the cost of medicines, of molluscicides, and of preventive and clearance works. As a rule, too, the countries in which bilharziasis is rife are not wealthy, and cannot, unaided, attack the disease on the scale required to make an impression on it. International action and assistance are therefore essential.

International action before WHO

The complexity of the problem of bilharziasis was not widely appreciated before the Second World War, nor was there any clear understanding of the extent to which the debility and physical incapacity the disease causes hamper food production and involve countries where it is endemic, and which can ill afford it, in considerable economic loss. In 1938 the Egyptian delegate to the Health Organisation of the League of Nations proposed the establishment of

a Schistosomiasis Commission,[7] to undertake work on bilharziasis analogous to that of the existing Malaria Commission. A meeting of experts was convened,[8] and they recommended in a report that research be undertaken into problems of epidemiology, prophylaxis, education and propaganda. Nothing came of these recommendations, and for this a variety of reasons have been suggested: it was held that the experts were not representative of the areas where bilharziasis was endemic; that there was a shortage of information about the disease; and that the Health Committee as a whole did not discuss the proposals, so that the problem of bilharziasis was not fully ventilated. These reasons may well be valid, but the main reason why the recommendations fell into abeyance was the imminence of war, with the disturbance it entailed in League activities.

During the war the United States was suddenly faced with an outbreak of the disease among its troops in China, the Philippines and the islands of the Pacific. At one time over 3000 soldiers were invalided home with acute *S. japonicum* infections. The United States defence departments took immediate and vigorous steps to combat the disease, and the net result of this confrontation of a wealthy and advanced nation with a hitherto relatively obscure and neglected tropical disease was to stimulate interest in and research into the public health and medical problems it presented.

WHO studies the problem

When the Interim Commission of the World Health Organization met after the Second World War, Dr Aly Tewfik Shousha,[9] the Egyptian member, proposed that bilharziasis be placed on the agenda of the First World Health Assembly. At the request of the Interim Commission he prepared a memorandum with the title "Schistosomiasis (bilharziasis), a world scourge", and presented it to the fourth session. His description of bilharziasis and its effects led the Interim Commission to recommend that WHO collect data on the incidence and distribution of the disease, on measures taken to combat it, and on its economic effects; provide governments with the fullest possible information on it; and set up an advisory committee of experts to study it.

The First World Health Assembly in 1948 adopted the Interim Commission's recommendation, and agreed that a committee of experts on parasitic diseases and a panel of experts possessing specialized knowledge of such diseases be established, that the staff for this group of diseases include at least one well-qualified parasitologist with field experience, and that the first object of study be bilharziasis.[10] In due course an Expert Committee on Bilharziasis was set up, but before it met WHO, jointly with the Office International d'Hygiène Publique (OIHP), convened a group of experts to examine the problem of bilharziasis in Africa.

This Study Group on Bilharziasis in Africa met in Cairo in October 1949, in the office of the Bilharzia Snail Destruction Section of the Egyptian Ministry of Public Health.[11] It called for surveys of the incidence and intensity of bilharsiazis throughout the world so as to provide a complete and more accurate picture of its geographical distribution; and stressed the importance of uniform surveying methods, and the need for sufficient staff to carry out the surveys. The distribution of the snail vectors also required determination, and here uniform classification and nomenclature were essential. Hitherto classification had been based on the external characteristics of the shells, but this system had caused complication and confusion, and needed to be replaced by classification based on the internal morphology of the snails and their ecological characteristics. It was suggested that WHO should

[7] Hilmy, A. (1938) *Proposal to establish a Schistosomiasis Commission ...*, Geneva (League of Nations Health Organisation, C.H. 1351)

[8] League of Nations Health Organisation (1938) *Consultation of experts on bilharziasis (schistosomiasis)*, Geneva (C.H. 1395)

[9] Dr Shousha later served as Director of the WHO Regional Office for the Eastern Mediterranean from 1949 to 1957.

[10] *Off. Rec. Wld Hlth Org.*, 1948, 13, 309

[11] *Wld Hlth Org. techn. Rep. Ser.*, 1950, 17

make arrangements to facilitate and standardize the identification of specimens.

The Joint Study Group then discussed the significance of bilharziasis as a cause of mortality, morbidity, and loss of productive power. Quantitative knowledge was required of the relationship between the incidence and intensity of the infection and the loss of productive power in the individual, with the economic consequences this entailed. Not enough was known about the development of immunity after infection, and here too research was required.

Diagnostic methods in use were many, and often the results they achieved were not comparable. The Joint Study Group accordingly examined and weighed the pros and cons of various methods of diagnosis, and made certain recommendations for improvement or increased uniformity.

The Group then turned to the question of bilharziasis control. " Although a number of methods have yielded results ", it observed, " that appear to make the above objects [prevention of the pollution of streams, destruction of the intermediate hosts, sterilization of the human reservoir] attainable, yet no one single method has proved entirely or permanently successful and brought about the eradication or even satisfactory control of the disease. It would appear that a combined attack on the disease by several methods is required to meet with success. " [12] The Group examined the various methods that had been tried to prevent the pollution of streams, to destroy the snails, and to treat the patients. It recommended, among other things, that WHO grant fellowships in bilharziasis survey and control, for a considerable part of the problem of control was due to the lack of properly trained staff in the field.

Finally, it sounded a note of warning about the relationship between irrigation schemes and the spread of bilharziasis, and recommended various precautionary measures that might mitigate the sanitary risk involved. These included administrative and technical safeguards, and postulated close co-operation between the irrigation engineering staff and the public health authorities. The Executive Board of WHO, noting this warning, requested the Director-General to bring the dangers mentioned, and the Joint Study Group's recommendations, to the attention of governments and international organizations interested in irrigation schemes, and a letter to that effect was duly dispatched.

The WHO Expert Committee on Bilharziasis met in Puerto Rico in 1952. By then some surveys of the geographical distribution of bilharziasis in various areas had been carried out, in accordance with the recommendations of the Joint Study Group, and were before the Committee. But it was compelled to conclude that the information available, while showing the wide distribution of actual and potential vectors of bilharziasis in tropical and subtropical areas throughout the world, and of human infection from various schistosome species, " gave no adequate measure of the true prevalence and severity of bilharziasis as a disease or as a cause of disability or of death ".[13] This was hardly surprising, it added, as most health administrations were themselves ignorant of the true extent of infection in their own territories. The Committee accordingly recommended that WHO sponsor and publish surveys of the disease and of the distribution of vector snails. In order to simplify identification of vector snails, the publication of comparatively easy keys for the determination of species would be of great value to the non-specialists who would necessarily be engaged on such surveys.

The Committee also made a critical analysis of methods of diagnosis of bilharziasis, with special reference to their applicability; for, while a presumptive diagnosis was possible in a known endemic area, many errors resulted from unsupported clinical diagnoses, since several other diseases simulated bilharziasis. Thus, laboratory diagnosis was essential, and standardized and accurate methods were required to make the results comparable, whatever the laboratory in which the diagnosis was made.

There was continuing confusion about the

[12] *Wld Hlth Org. techn. Rep. Ser.*, 1950, **17**, 8

[13] *Wld Hlth Org. techn. Rep. Ser.*, 1953, **65**,

status of many species of snails, in spite of the arrangements WHO had made in 1950, in accordance with the Joint Study Group's recommendation, for expert identification of specimens. The Committee recommended that those arrangements be continued and expanded, and that three malacologists possessing a special knowledge of vectors of human schistosomes undertake identification of specimens forwarded by health administrations and interested individuals. The ecology of molluscan intermediate hosts, the ability of certain species to serve as vectors, vector-parasite relationships—particularly the influence of chemical, physical and meteorological environmental factors on the susceptibility of snails to schistosome infection—and the physiology of intermediate hosts all required additional study, for they might provide clues to variations in susceptibility to infection and to the mode of action of molluscicides.

The Committee noted that, in spite of WHO's cautionary notice to governments on the risk of introducing, or extending the range of, bilharziasis as a result of irrigation schemes, co-operation between health administrations and irrigation authorities had not been achieved in many areas, or had not been as close as was necessary. The need for screening and treating the human population when it migrated, as it was doing on a large scale in Africa, especially when it migrated into an irrigated area, was most important; and the local authorities were responsible for providing the population with sanitary equipment and conditions and adequate health education in order to cope with the increased risk due to its concentration. This concentration of the population made such measures practicable, as they would not be if it were scattered.

The Committee made recommendations regarding the standardization of procedures for epidemiological surveys of bilharziasis, the measurement of its incidence and its social importance, morbidity and mortality rates, its anatomical localization, clinical gravity, and complications, the study of conditions—geographical, helminthological, malacological and human—governing its transmission, and the lines along which preventive action should be taken. " Assessment of the local factors governing the effectiveness of each preventive action, " it held, " is in practice the most important part of a bilharziasis survey. It is also the most complicated. What is required is the integration of bilharziasis control measures in the health programme and even in the general economy of the country." [14] There should therefore be studies of conditions governing transmission of the disease, of economic conditions and of ethnological conditions in the area or country affected; and the results of previous experiments in prophylaxis should be carefully assessed.

The Committee then turned its attention to control methods, and particularly to the use of molluscicides and other means of snail destruction, which it considered to be the most important single method of preventing bilharziasis. It reviewed at length the qualities desirable in an ideal molluscicide, and the molluscicides available, discussing the extent to which they fell short of the ideal; noted that biological methods of control had not received the attention they deserved; and made various recommendations for more effective snail control.

Finally, it examined methods of treatment. There was much variation in the behaviour of the same parasite in different localities, so that it was necessary to establish a method of treatment for each area. Standards and methods of assessing cure had altered a great deal in recent years, and it was difficult to compare work with what had been done years before. It would therefore be a most useful service to test drugs in common use again in as many endemic areas as possible, so that therapeutic efficiency tables might be compiled for each area.

Within a short time of the Expert Committee's meeting, there was an opportunity to put the recommendations of the Joint Study Group and the Expert Committee on Bilharziasis into effect. The United States Army in the Philippines had discovered the prevalence of *S. japonicum* infection there

[14] *Wld Hlth Org. techn. Rep. Ser.*, 1953, **65**, 30

during the war. A survey of the disease was carried out in 1949-1950 [15] under a bilharziasis research programme instituted by the Department of Health of the Philippines, and as a result the Government created a Division of Schistosomiasis in that Department in 1951 to cope with a problem whose importance was made evident by the survey. At the request of the Government, WHO sent a team of consultants to the Philippines in 1952 to examine what was being done and to make recommendations for a national programme. The team came to the conclusion that thinly spread efforts to deal with the disease would be more or less unrewarding, and that it would be better to concentrate funds and efforts on a pilot project in the island of Leyte, which appeared to be the most important endemic area. In 1953 the project was started, with WHO advisers and aid, and with assistance also from the Foreign Operations Administration of the United States and from the Philippine Council for United States Aid. This was the first large project carried out internationally, under the auspices of WHO, for the control of bilharziasis.

The Leyte bilharziasis project is discussed at length in another article.[16] It provides an admirable illustration of the painstaking and time-consuming studies required as a preliminary to controlling bilharziasis, and of the results that can be achieved if the attack on the disease is conducted on a wide front and with proper planning.

Both the Joint Study Group and the WHO Expert Committee on Bilharziasis had emphasized the confusion regarding the status of many species of snail vector. WHO accordingly convened in Paris in 1954 a Study Group on Bilharzia Snail Vector Identification and Classification.[17] This Group considered principles of classification and criteria for identification, discussed the knowledge already available on the snail vectors, made suggestions on the essential data that should accompany all collections sent for identification, and submitted recommendations for future research and international co-ordination. It also compiled a tentative list of various African species of *Biomphalaria* which were known or suspected to be vectors.

Yet another obscure subject noted by the Expert Committee on Bilharziasis was the relationship between the ecology of the habitats of snail vectors, their life cycles, their breeding and other habits and the process whereby they infected man. WHO convened yet another body of experts to consider this problem, the Study Group on the Ecology of Intermediate Snail Hosts of Bilharziasis, which met in Paris in 1956.[18]

The Study Group examined the distribution of intermediate snail hosts in relation to hydrogeology and factors influencing their habitat and breeding conditions: physical factors such as temperature, light intensity, the movement, depth and level of water, desiccation; chemical factors such as salinity, ion balance, hydrogen-ion concentration; general factors such as pollution; and biological factors such as natural enemies and predators, parasites and diseases, food preferences, and vegetation. Seasonal and climatic factors influencing their life cycle were also discussed. In the light of the knowledge available concerning the ecology of these snails, the Study Group then considered bilharziasis control measures, the use of molluscicides, sanitation, irrigation engineering, water management, and modifications in fishing and farming practices, and made various suggestions about each of these subjects. Some of these methods of controlling bilharziasis are reviewed at greater length in other articles.

The Study Group wound up its meeting with various proposals regarding methods of sampling to be used in measuring the density of mollusc populations during surveys and for the evaluation of results of control methods, and made suggestions for further studies in ecology and physiology in relation to control methods. It noted that the development of ecological research had now reached a point where extensive field studies could no longer be carried out by individuals,

[15] *Bull. Wld Hlth Org.*, 1958, **18**, 364

[16] See page 39.

[17] *Wld Hlth Org. techn. Rep. Ser.*, 1954, **90**

[18] *Wld Hlth Org. techn. Rep. Ser.*, 1957, **120**

so that co-operation between specialists in different disciplines was required. Such co-operation might have to be international in nature, as few countries could themselves provide all the experts needed.

Later in 1956 WHO convened an African Conference on Bilharziasis, which met in Brazzaville, French Equatorial Africa.[19] The Conference examined the series of surveys of bilharziasis made by WHO consultants between 1950 and 1956 in accordance with the recommendations of the Joint OIHP/WHO Study Group and the Expert Committee on Bilharziasis, and suggested that maps be produced to show the distribution of the disease, of each of the intermediate hosts, and of animal schistosomiasis. It discussed the distribution of each of these in detail, and the gaps in existing knowledge, noting that, in the whole of Africa south of the Sahara, there were only a few areas where bilharziasis did not occur.

One of the great dangers in Africa was, as earlier WHO reports had noted, the spread of bilharziasis by the introduction or extension of irrigation schemes. A sharp increase in infection had already occurred in one region of the Belgian Congo, and in the Eastern Transvaal.

The Conference discussed problems related to the victim of the disease, to morbidity and mortality—noting that certain signs and symptoms had to be taken into consideration when an attempt was made to evaluate the degree of morbidity due to the disease—to methods employed in epidemiological surveys, to reinfection, receptivity, and resistance to infection, to the possible connexion between diet and the pathogenicity of the parasite, to associated psychological disturbances, and to the moot question whether human schistosomes had a carcinogenic action. Turning to the factors influencing the epidemiology of bilharziasis, it examined the intermediate host-parasite complex, the importance of animal reservoirs, the influence of human concentration, and the extension of irrigation operations. Each of the molluscicides in common use received attention, then the problem of mass treatment as a method of control, and parasitological and immunological means of assessing cure. The Conference made recommendations on all these subjects, as well as on environmental sanitation measures, on water management, on health education, on the need for collaboration between health authorities and the governmental and private agencies concerned in the study and execution of control measures, and on international co-ordination of bilharziasis control and research, exchange of information, and training of personnel. Many of these recommendations endorsed earlier recommendations by WHO groups and committees, which the Conference wished to reinforce with all its authority, particularly as in many cases they had by no means been put completely into effect.

The Joint Committee on Health Policy of the United Nations Children's Fund (UNICEF) and WHO discussed, and produced reports on, the progress of bilharziasis control programmes at their tenth[20] and eleventh[21] sessions. UNICEF is particularly interested in bilharziasis because the usual epidemiological picture of this disease is one of high incidence in the younger age-groups. The data obtained by WHO consultants in Africa show that the infection rate for children is much higher than for adults. They become infected at the age of two years, or as soon as they are able to walk, and are responsible for making local endemicity high in rural areas, because of their habits of playing in the water and of indiscriminate pollution. Eggs excreted by children hatch more easily and have greater infectivity, and the transmission index,[22] is therefore relatively higher. In the Leyte bilharziasis project, for example, it was found that this index, which was 1.2% for the age-group 50-59 years, was 59.9% for the age-group 10-14 years.

WHO surveys and control projects

WHO's policy in respect of bilharziasis is based on the findings and recommendations of its various committees, study groups and

[19] *Wld Hlth Org. techn. Rep. Ser.*, 1957, 139

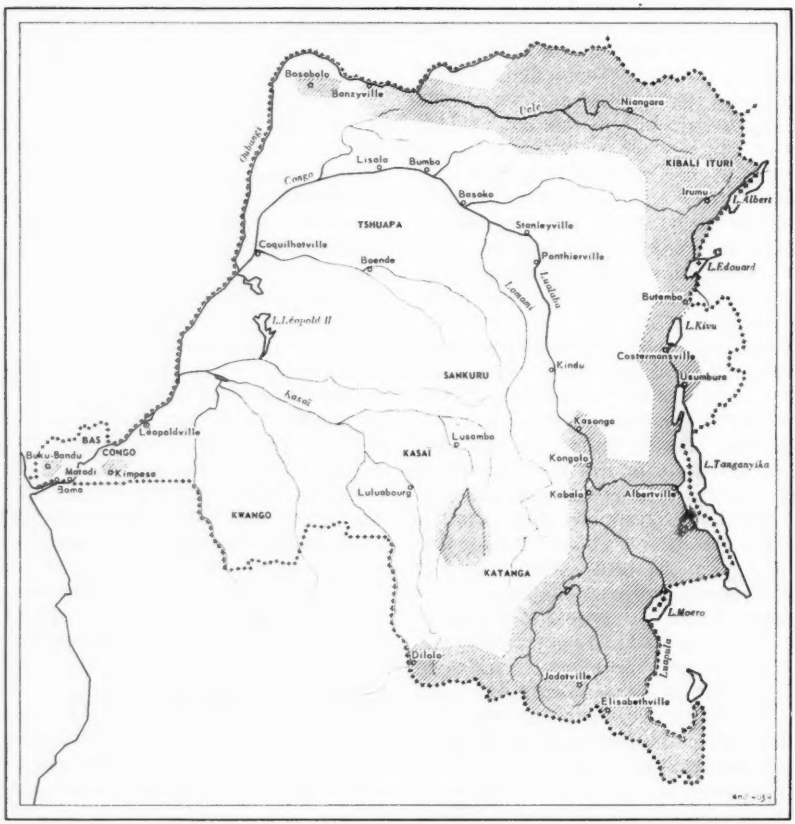
[20] Unpublished working document JC10/UNICEF-WHO/3

[21] Unpublished working document JC11/UNICEF-WHO/4

[22] See page 47.

conferences on the subject. Among its aims are the identification and classification of the intermediate hosts and the parasites; the study, in laboratories and in the field, of the ecology of the snail vectors; the development of standard methods in epidemiological surveys; the study of water management and engineering techniques for the prevention of the spread of bilharziasis; co-operation between the biologists, zoologists, chemists, engineers, health educators and public health officials whose joint efforts are a prerequisite for the successful control of the disease; the provision of training courses for the specialized staff required; the development of new molluscicides and better formulations with a view to increasing their efficacy, rendering their application easier, and reducing the cost of treatment; the development and trial of new therapeutic drugs; and the study, through pilot projects, of local epidemiology, and of human, animal and snail ecology,

FIG. 1. DISTRIBUTION OF BILHARZIASIS DUE TO *S. MANSONI* IN BELGIAN CONGO

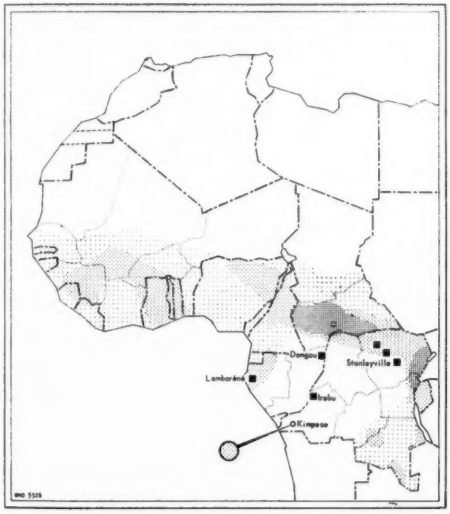


Areas where bilharziasis is found

so that advice can be given on the most economical and effective methods of control of the disease.

In carrying out this policy, WHO has sent teams of experts to make surveys of the geographical distribution of bilharziasis and of the intermediate hosts of the schistosomes in Africa, the Eastern Mediterranean and the Philippines. Investigations were undertaken in African territories between 1950 and 1952, and later surveys were made in 1955 and 1956. The first of these surveys covered the Belgian Congo and Ruanda-Urundi.[23] Here intestinal bilharziasis caused by *S. mansoni* is endemic in a large area (see Fig. 1); infection by *S. haematobium* is relatively unimportant.

FIG. 2. INCIDENCE OF BILHARZIASIS DUE TO *S. MANSONI* AND DISTRIBUTION OF *S. INTERCALATUM* IN WEST AND CENTRAL AFRICA, 1948-1950

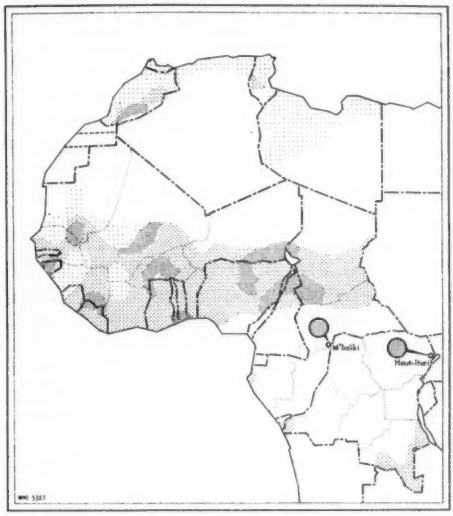


High incidence
Moderate incidence
Low incidence
} S. mansoni

▪ *Foci of* S. intercalatum

[23] *Bull. Wld Hlth Org.*, 1954, **10**, 315

FIG. 3. INCIDENCE OF BILHARZIASIS DUE TO *S. HAEMATOBIUM* IN WEST AND CENTRAL AFRICA, 1948-1950



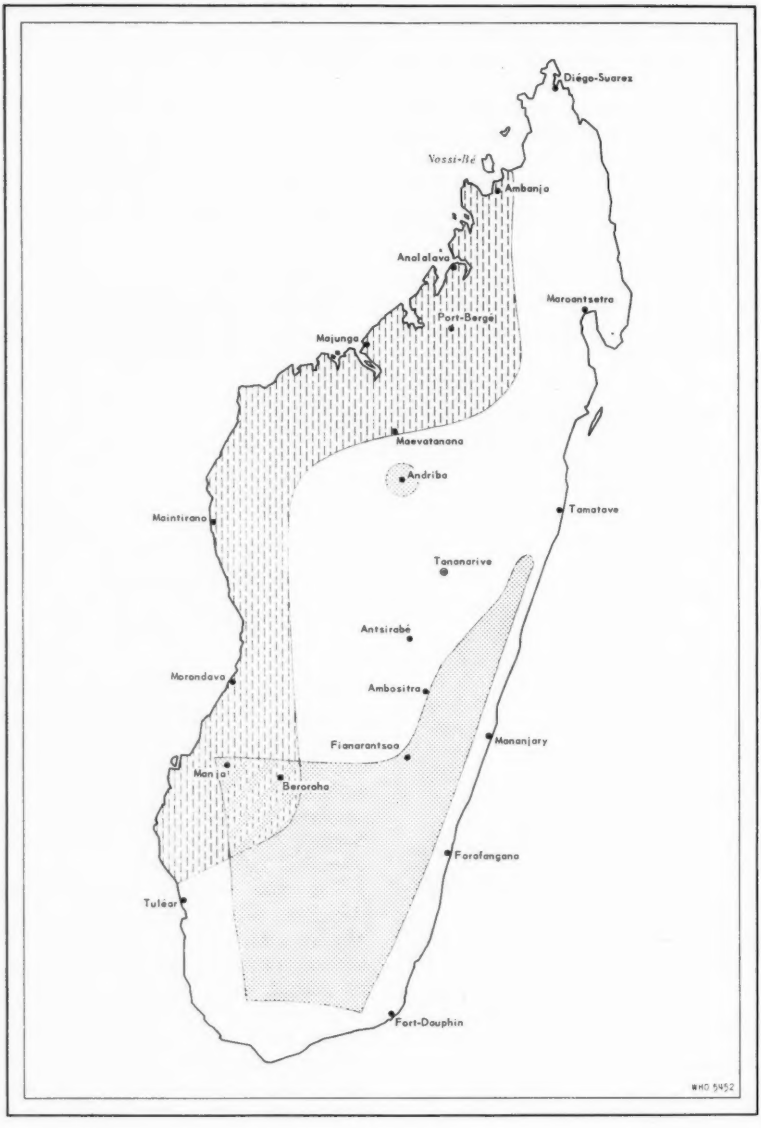
High incidence
Moderate incidence
Low incidence

The second survey dealt with bilharziasis in Western and Central Africa,[24] (see Figs. 2 and 3), where infection by both *S. mansoni* and *S. haematobium* is widespread and there are isolated centres of infection by *S. intercalatum*, a species, found sporadically in the Belgian Congo as well, which also causes intestinal bilharziasis.

The next survey[25] was of Madagascar, Réunion and Mauritius (see Fig. 4). In Madagascar, whereas infection by *S. haematobium* is confined to the western portion of the island, infection by *S. mansoni* is found only on the southern half of the east coast, except for a small area which overlaps that of *S. haematobium*. Two-fifths of the island are free from the disease, and Réunion is completely free. In Mauritius only the urinary form is present, but the incidence is

[24] *Bull. Wld Hlth Org.*, 1955, **13**, 209
[25] *Bull. Wld Hlth Org.*, 1955, **13**, 259

FIG. 4. BILHARZIASIS IN MADAGASCAR



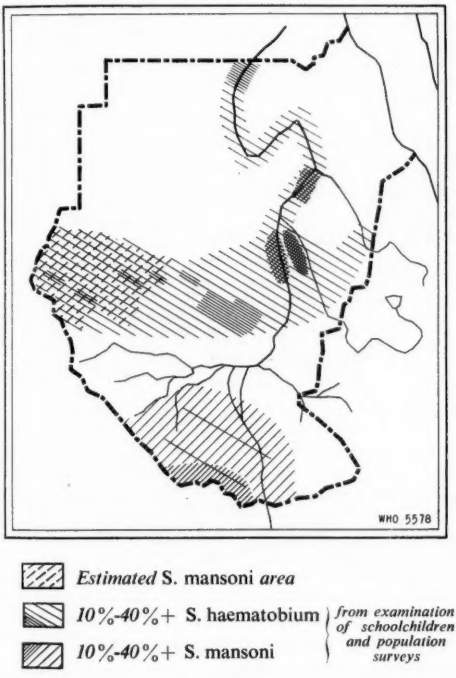
Bilharziasis due to S. haematobium

Bilharsiasis due to S. mansoni

low and the disease does not present a serious public health problem.

Another survey covered British Somaliland, Eritrea, Ethiopia, Somalia, the Sudan, and Yemen; [26] yet another the Eastern Mediterranean Region,[27] including Iraq, Israel, Jordan, Lebanon, Saudi Arabia, and Syria. Bilharziasis of both kinds is particularly prevalent in the Sudan (see Fig. 5) and the urinary form is endemic in Iraq (see Fig. 6), where the situation was compared to that of Egypt a century ago, before the intensification of agriculture and the ensuing sharp increase in population. "The health problems that will be created after the completion of the great irrigation works planned and partly under way in Iraq might well be viewed with alarm." [28] The other Eastern Mediterranean countries surveyed are relatively little affected by the disease, but some contain foci of disease, others suitable habitats for the vector snails. Other surveys were of British West and East Africa and the Federation of Rhodesia and Nyasaland; [29] of Basutoland; [30] of Bechuanaland; [31] and of the British Cameroons.[32]

FIG. 5. BILHARZIASIS IN THE SUDAN

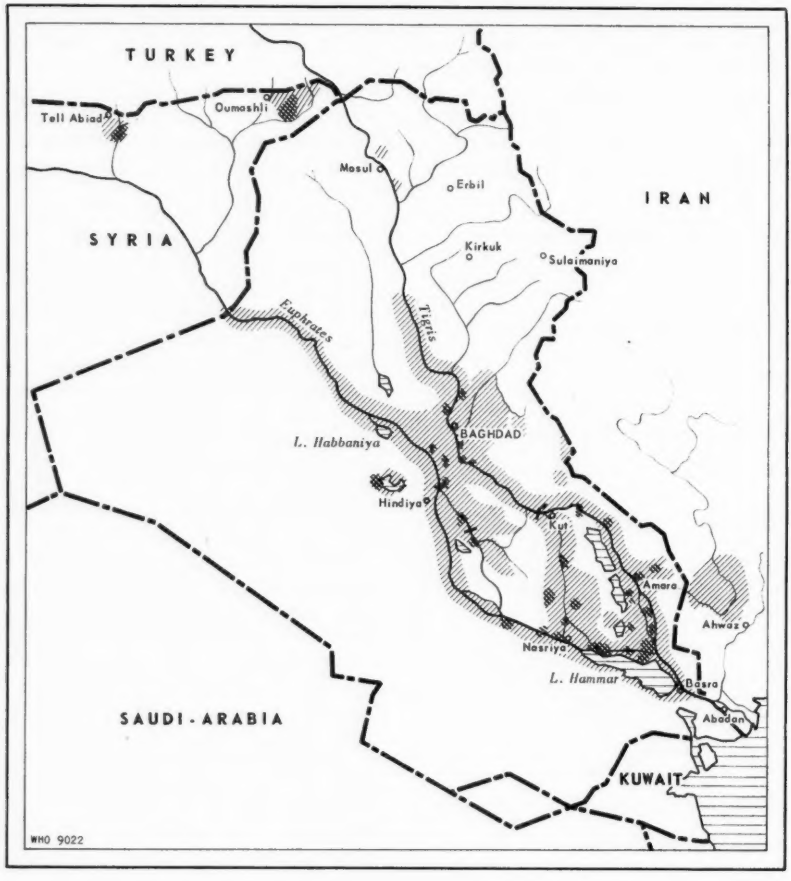


These surveys were submitted to the African Conference on Bilharziasis in 1956.[33] They sought, not only to assess the incidence and prevalence of the disease in the territories with which they were concerned, but also to establish the geographical distribution of possible vector snails and to describe the treatment and methods of control in use. And they provided the first picture, admittedly an incomplete one, of the distribution of bilharziasis in Africa and the Eastern Mediterranean Region, of the directions in which it might spread, and of what was being done to control it.

WHO has also encouraged three central laboratories of malacology—in Copenhagen, Paris, and Salisbury, Rhodesia—to study the identification of the species of snails collected during surveys; the close collaboration between these centres and workers in the field has made it possible to make a provisional map of the geographical distribution of intermediate hosts in Africa. A monograph on the African Planorbidae has been prepared,[34] and it is hoped that the American Planorbidae will also be described. Knowledge of the ecology of the intermediate hosts has been greatly advanced by the Leyte bilharziasis project. A WHO team working in East Africa in the Institute of Malaria and Vector-Borne Diseases, Amani, will also carry out ecological studies of snails as part of its work.

[26] *Bull. Wld Hlth Org.*, 1956, 14, 1
[27] *Bull. Wld Hlth Org.*, 1956, 14, 403
[28] *Bull. Wld Hlth Org.*, 1956, 14, 416
[29] *Bull. Wld Hlth Org.*, 1956, 15, 203
[30] *Bull. Wld Hlth Org.*, 1958, 18, 1049
[31] *Bull. Wld Hlth Org.*, 1958, 18, 1051
[32] *Bull. Wld Hlth Org.*, 1958, 18, 1052
[33] See page 13.
[34] Mandahl-Barth, G. (1958) *Intermediate hosts of* Schistosoma, Geneva (*World Health Organization: Monograph Series*, No. 37)

FIG. 6. ENDEMIC BILHARZIASIS IN IRAQ



Methodology in epidemiological surveys has also received great impetus from the Leyte bilharziasis project, in which standard techniques have been developed for the study and measurement of the disease in man and in animals, for the assessment of methods of control, and for the determination of the relationship between the infection and its economic effects on the individual. WHO is carrying out skin-testing experiments in Iraq and encouraging their trial in Iran, so as to standardize this method of diagnosis of bilharziasis and assess its value as an epidemiological tool.

WHO, with the assistance of two expert consultants—an epidemiologist and an irrigation engineer—has now begun the study of problems of control and prevention of the spread of bilharziasis in relation to irrigation engineering practices. An advisory team of consultants has been sent to countries where irrigation schemes may lead to such an extension in the range of the disease, with a view to developing practical methods of obviating the danger.

The provision of sufficient qualified staff to carry out surveys and help in the control of bilharziasis has been advocated constantly since the first WHO advisory groups met to consider this disease. They have all stressed the need to train key workers in malacology, ecology, epidemiology, parasitology and sanitary engineering. WHO has accordingly given high priority to training, and has organized an inter-regional training course in bilharziasis for key workers such as epidemiologists, biologists and sanitary engineers.

Finally, apart from those surveys which WHO carries out itself to determine the distribution of the disease or of the snail vectors, or at the request of governments to assess the extent of the problem of bilharziasis in their territories, it assists governments in the control of the disease in Egypt, Syria, Iraq and the Philippines, and is in close touch with work carried out in the Latin American countries with the assistance of its Regional Office for the Americas. Demonstrations of methods of control have been given in Eastern Mediterranean countries. Assistance is also to be given to new control projects in the Federation of Rhodesia and Nyasaland, Ghana, Somalia and Iran. It is WHO's policy to adapt methods to local conditions, and not to launch upon any large-scale scheme of control until carefully planned pilot experiments are carried out. In Egypt and Iraq preliminary surveys were made as a basis for the planning of projects; and in the Philippines they are an essential aspect of the programmes.

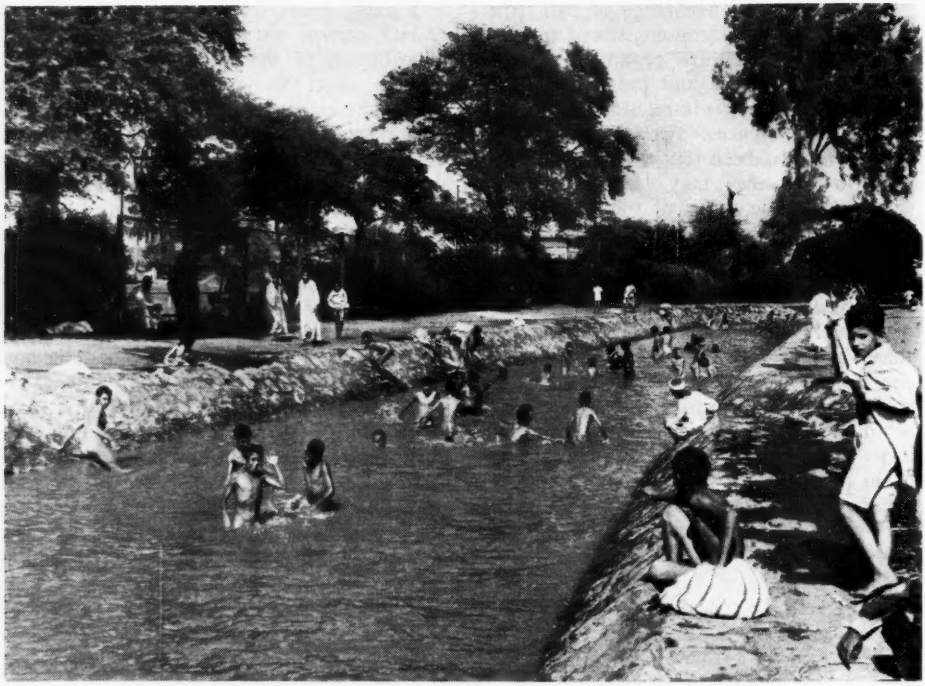
BILHARZIASIS AS A MAN-MADE DISEASE

It is a tragic irony that in many parts of the world the vast irrigation schemes constructed with the aim of improving the standard of living have had the effect of undermining the health of the areas they serve. The networks of canals designed to carry water to arid territories have proved ideally suited for carrying bilharziasis—and sometimes other diseases—to the inhabitants. Still more important is the fact that before the introduction of perennial irrigation, bilharziasis was almost unknown in many of these areas. For this reason, bilharziasis has been termed a " man-made " disease.

The connexion between irrigation and bilharziasis was sometimes overlooked by irrigation engineers in the past, but as early as 1937 careful surveys conducted in the Quena and Aswan provinces of Egypt provided striking confirmation of the relationship. Within three years of the introduction of perennial irrigation in these provinces, the prevalence of bilharziasis showed the following increases:

	Percentage of population infected	
	1934	1937
Sibaia	10	44
Kilh	7	50
Mansouria	11	64
Binban	2	75

A similar correlation was observed in the Belgian Congo, where in one area the bilharziasis infection rate increased from 3-4% to 30-35% in the space of 12 months following the extension of rice irrigation schemes, and many of the new cases were more severe than those previously encountered. In Southern Rhodesia, the Umshandige Irrigation Scheme, costing three million pounds, had to be abandoned in 1949, ten years after its commencement, mainly because the prevalence of bilharziasis had reached such menacing proportions.



An irrigation canal in the Eastern Mediterranean Region, perfect for a cooling bathe on a hot day, equally perfect also for infection by cercariae emerging from the vector snails which find in such a canal an ideal habitat.

Unheeded warnings

The spreading of bilharziasis through irrigation schemes has been of concern to WHO since its inception, and repeated warnings have been sent to governments, particularly those responsible for the administration of non-self-governing territories. The Joint OIHP/WHO Study Group on Bilharziasis in Africa,[1] which met in 1949, drew attention to the problem, and proposed a number of administrative and technical safeguards, including close collaboration between the public health authorities and those responsible for planning irrigation schemes. In 1950, the WHO Executive Board requested that these recommendations should be brought to the attention of governments and of the appropriate bodies and specialized agencies of the United Nations interested in irrigation. Three years later, however, the WHO Expert Committee on Bilharziasis noted in its first report: [2]

> " In spite of the formal cautionary notice issued by WHO to all governments and interested intergovernmental agencies, on the risk of introducing or increasing the intensity of bilharziasis as a result of irrigation schemes, it is obvious that co-operation between health administrations and the authorities responsible for irrigation has not in many areas been achieved or been as close as was necessary."

And the Department of Health for Southern Rhodesia noted in its annual report for 1953: [3]

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1950, **17**

[2] *Wld Hlth Org. techn. Rep. Ser.*, 1953, **65**

[3] Southern Rhodesia (1954) *Report on the public health for the year 1953*, Salisbury, p. 8

" Despite continual advice given by the Health Department, irrigation schemes are planned and developed without due consideration of the health aspects. There is absolutely no doubt that every irrigation area in the Colony will become infested with vector snails which will eventually become infected with bilharziasis unless the danger is realized at the outset, and plans for prevention made. The statement has been made before, and must be made again, that large irrigation schemes may well wreck the health of the country and bring the most grandiose schemes to a pitiful end."

WHO is continuing its efforts to press home this lesson. In a report on public health conditions in the non-self-governing territories submitted to the United Nations in 1955,[4] it referred to the concern of medical authorities in some of the territories about the large number of irrigation schemes being carried out without previous consultation with health officers. The report continued:

" These important schemes with their large dams and extensive networks of waterways are essential to agricultural development and are potentially a source of much good to the people, since they represent the hope of more food and a better standard of living, and therefore better health. But this object may be defeated if there is lack of co-operation between all concerned at the beginning, and if, as a result, much bigger and better breeding places for infected snails and other disease vectors are provided."

Two papers recently published in the WHO Bulletin [5] again draw attention to the seriousness of the situation and discuss the ecological and engineering aspects of snail control in engineering systems. Some of the more important considerations and recommendations are summarized below.

Where snails thrive

Not all parts of an irrigation system are equally suitable for the development of bilharziasis intermediate hosts. A comparison of the conditions in those sections where the snails thrive and those where they do not, taken in conjunction with studies of natural habitats, provides valuable pointers to the control methods that might be applied by the engineer. Thus it is observed that the snails are confined mainly to the smaller branches of the canal system. They are usually absent from the main feeder canals where the swifter flow of water and high turbidity create unfavourable conditions. Again, the smaller channels that are lined with brick, stone or cement are usually free from snails, because they do not support plant life for the snails to feed on; but they are often found where a deposit of silt forms and aquatic plants grow. In general, mud-lined channels with a gentle flow of water offer the most favourable habitats for bilharziasis snails. Even if such channels are allowed to dry out from time to time, many of the snails are able to survive in the bottom mud, particularly where the ground-water level is sufficiently high to keep the earth moist and cool. However, in channels that repeatedly dry out completely, the snails are unable to maintain an existence. If the canals are lined with concrete or similar material, drying out even for short periods will kill all snails and their eggs.

Large reservoirs are not, as a rule, good habitats for bilharziasis vectors, but such snails may be found in shallow, sheltered bays created by irregularities in the shore.

Other parts of irrigation channels that form excellent habitats for snails are culvert-heads, drainage channels carrying water away from irrigated areas, and the tail-pools that form at the end of irrigation channels in some systems. Seepage pools and channels do not usually harbour snails, as they are very shallow, subject to large and rapid changes of temperature, and often of a temporary nature.

Food and water

It is obvious that no body of water can support a snail colony unless it provides suitable food. As pointed out in an ecological study reported recently in the WHO Bulletin: " The food of bilharziasis vectors is largely vegetal, consisting of microflora which form the main constituent of the

[4] United Nations (1955) *Special study on social conditions in non-self-governing territories*, New York, p. 74

[5] Watson, J. M. (1958) *Bull. Wld Hlth Org.*, **18**, 833; Lanoix, J. N. (1958) *Bull. Wld Hlth Org.*, **18**, 1011

slimy layer encrusting the submerged plants, and commonly known as periphyton. These microflora multiply rapidly to form a scummy layer on the submerged stems and leaves of plants, on the under-surface of floating leaves, on the bottom mud, on stones, on gravel and on any flotsam." [6] The presence of this periphiton or plankton—mainly algae—is essential for the establishment of breeding colonies, as the young snails are dependent on this type of food, at least in some species. On the other hand, even adult snails can subsist on this diet alone. This is important because a growth of algae will sometimes appear on the sides of channels lined with brick, stone or cement if the flow of water is gentle and continuous, and snails may then make their appearance.

Snails do not appear to be very dependent on the physical or chemical nature of the water; they are tolerant of a wide range of pH, hardness and alkalinity, and numerous analyses of waters from different habitats have failed to reveal a consistent pattern in the mineral composition. The salinity of the water appears to be the most important limiting factor, and in Africa snails are rarely found in waters which contain less than 10 parts per million (p.p.m.) or more than 430 p.p.m. of dissolved salts, although in Iraq *Bulinus truncatus* is found in waters with a salinity up to 1010 p.p.m., and even higher concentrations are tolerated in the laboratory. Strongly acid waters may be fatal to snails but are rarely encountered in practice. The extremes of water quality that would be unfavourable to snails would not be acceptable for agricultural purposes. As Lanoix puts it: "Water which is good for irrigation is also good for snail development."

Weeds

Although young snails feed mainly on plankton and are not dependent on higher plants for food, the presence of aquatic weeds in irrigation canals favours the establishment of snail colonies for a variety of reasons. The plants slow down the current, oxygenate the water, and provide shade from excessive sunlight, shelter from predators, food for adult snails, and suitable surfaces on which the snails can crawl and deposit their egg-masses. Furthermore, the leaves and stems are usually covered with algae, and the decaying leaves themselves provide additional food and humus. But it is not only because weeds encourage snails that their presence in irrigation canals is undesirable. They also seriously impair the efficiency of the canals, clogging the irrigation structures and drains, reducing the capacity and velocity of flow, and permitting the deposit of silt. At the same time, they increase losses due to seepage and transpiration. The public health administrator, the farmer, and the irrigation engineer are therefore at one in wishing to keep the irrigation system as free from weeds as possible.

Control measures

Canal design

It is clear that any features of canal design that prevent the growth of weeds and algae will also keep the irrigation systems free from bilharziasis vectors. Though much work still needs to be done to establish which designs give the best results at the lowest cost, there can be no doubt that lining the canal with a hard material, such as stone, brick or concrete, almost entirely suppresses the growth of aquatic plants. The best of these materials is concrete. Asphalt or plastics usually require a further lining of earth and are not therefore of much value for reducing aquatic growth. In some areas where concrete linings have been tried they have proved extremely effective in keeping the canals free from snails, but it is not yet certain that they are equally satisfactory against all species and under all conditions.

Another important aspect of canal design is the speed at which the water flows, which is dependent on a number of factors, especially the steepness of the canal slope and the size and shape of the channel. A high velocity is desirable from the point of view of snail

[6] Abdel Malek, E. (1958) *Bull. Wld Hlth Org.*, **18**, 785

Making the sides of an irrigation canal perpendicular ensures that the current flows evenly throughout, and that the aquatic vegetation which provides food and refuge for vector snails obtains the least possible hold on them.

control and also has advantages for the irrigation engineer. The higher the velocity, the smaller is the canal section required. Construction costs are therefore reduced, although, for velocities exceeding 1.5 metres per second, this saving is offset by the expense of lining the canal to prevent erosion. In the long run, however, lined canals are cheaper, as they have a long life—at least 40 years for a good-quality concrete lining—and require little maintenance. With a high rate of flow, maintenance costs are further reduced because the deposition of silt is prevented. For the farmer, swift-flowing, lined canals offer the advantages of requiring a narrower right of way and hence saving land, and of preventing seepage losses, thus protecting lowlands from waterlogging and conserving water for crops.

Although snails are usually absent from fast-flowing canals, little is yet known regarding the maximum current velocities that are tolerated by them for varying periods of time and in the presence of different types and quantities of suspended matter. Breeding colonies of snails have been observed, however, in canals with a continuous flow of up to 20 metres per minute. The engineer and the malacologist on the spot must decide between them the most effective velocities that can be economically employed and which canals need a hard lining. Main

canals and the smaller distribution channels and furrows can often be left unlined, and it may be desirable and more practical to restrict the lining of secondary and tertiary canals to the portions situated near communities.

Covered irrigation systems

One way of eliminating both snails and weeds from irrigation systems is to distribute the water in pipes instead of in open canals. This also prevents infection of human beings and pollution of the water by urine and faeces, and, by keeping down mosquitos, is a valuable measure of malaria control. Closed systems, such as normally used for the distribution of domestic water, are initially very expensive, but semi-closed systems, which operate at lower pressures, seem to offer considerable promise and are receiving increasing attention in the United States, North Africa, and elsewhere. The simple covering in of the irrigation channels, a method formerly recommended, has not been found satisfactory. Although it shuts out sunlight and eliminates most aquatic growth, certain aquatic fungi, bacteria, and invertebrates are able to flourish and these permit the establishment of snail colonies.

In many areas, people are dependent on canal waters for washing and bathing. If the canals were to be replaced by a covered irrigation system, alternative facilities would have to be provided, and these should naturally be free from infection. The provision of chlorinated swimming-pools is highly desirable, but in addition it might be possible to make a piped irrigation system serve a dual purpose: the supply of water for irrigation and the supply of raw water for rural communities and individual farmhouses along the pipe route. Such a water-supply would still need purification, of course, to make it potable.

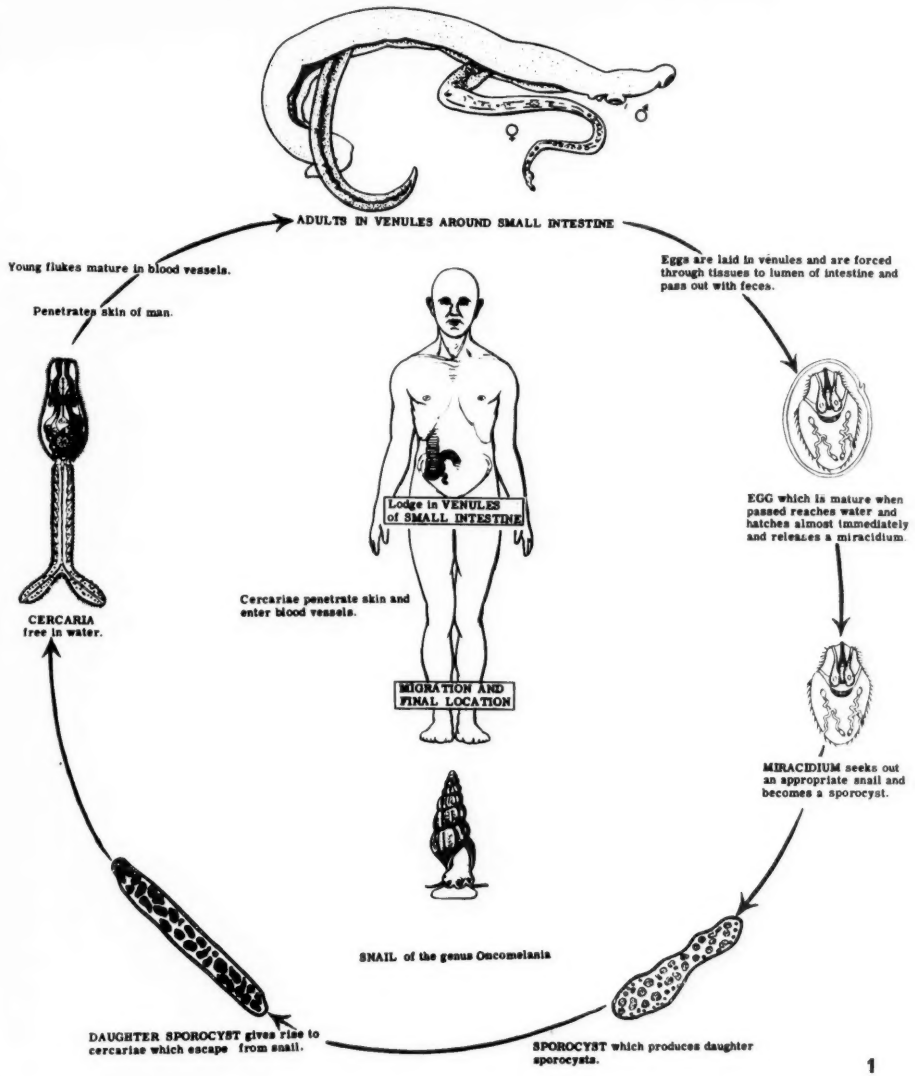
Other measures

Modifications in canal design appear to offer reasonable hope of successful snail control in irrigation systems, and, while initially they are expensive, in the long run they are likely to prove the most economical measure for the purpose. Various hand and mechanical methods of controlling weeds have been used, but they are not very effective, besides being cumbersome and expensive. Chemical control is also possible and much cheaper. Changes in water level are not very effective in reducing snail populations unless large, rapid and fairly frequent, but they may sometimes be of value in reservoirs. Culvert-heads are particularly favourite habitats for bilharziasis vectors and need special attention; they should be constructed entirely of cement and the floor should be at the same level as the culvert itself.

* * *

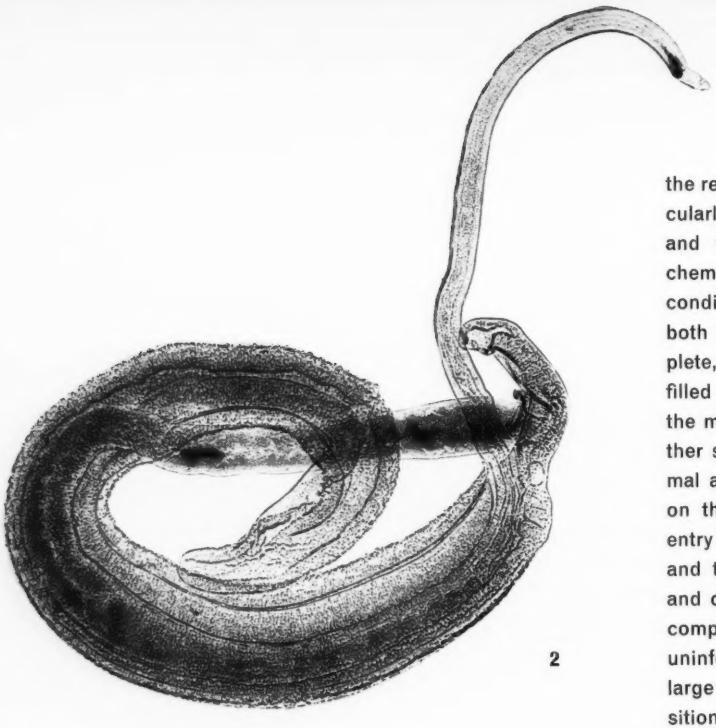
There is a great need for further research into snail ecology and the various aspects of canal design that influence the establishment of snail colonies. Above all, the engineer needs the guidance of the malacologist and the epidemiologist; experimental work and pilot studies by such a three-man team should go far towards establishing the most efficient snail-control measures that could be economically applied to the irrigation systems in any particular area. Irrigation could then become, as it was always intended to be, a boon and not a bane to the people of the " under-watered countries ".

BILHARZIASIS IN THE LABORATORY


♀
♂
ADULTS IN VENULES AROUND SMALL INTESTINE
Eggs are laid in venules and are forced through tissues to lumen of intestine and pass out with feces.
EGG which is mature when passed reaches water and hatches almost immediately and releases a miracidium.
MIRACIDIUM seeks out an appropriate snail and becomes a sporocyst.
SPOROCYST which produces daughter sporocysts.
DAUGHTER SPOROCYST gives rise to cercariae which escape from snail.
SNAIL of the genus Oncomelania
CERCARIA free in water.
Penetrates skin of man.
Young flukes mature in blood vessels.
Lodge in VENULES of SMALL INTESTINE
Cercariae penetrate skin and enter blood vessels.
MIGRATION AND FINAL LOCATION

1

Man is infected with bilharziasis from water in which swim cercariae, free-living forms of the schistosome parasite. The cercariae penetrate the skin and make their way to the liver, lungs, heart or main lymphatics; there they mature, and pair, then proceed to the mesenteric veins or the venous plexus around the bladder, where the females begin to lay their eggs. The eggs are voided in the urine or faeces, and hatch on contact with water, producing miracidia, which enter various species of snail, pass through further phases, and emerge as cercariae to complete the life cycle (**1**).



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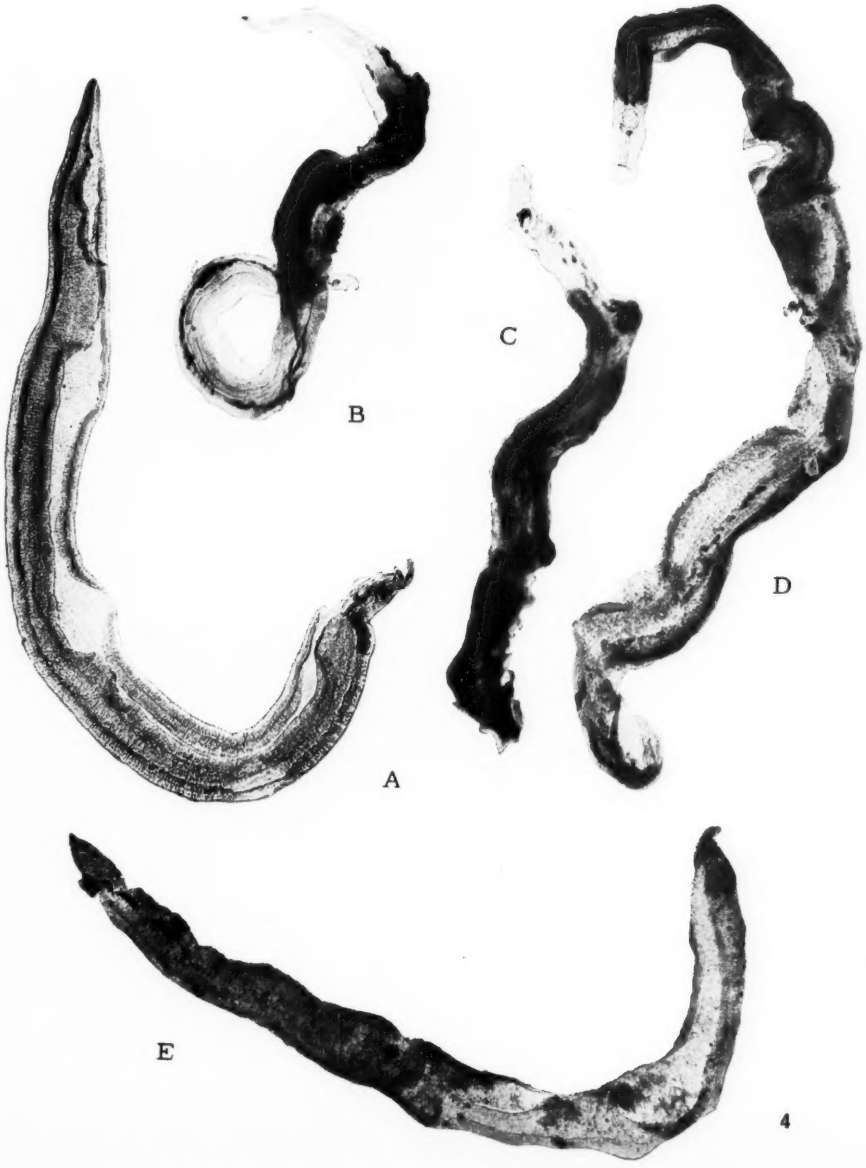
the results of infection on them, particularly on their powers of survival; and their susceptibility to various chemicals and diseases under varying conditions. Taxonomic knowledge of both vector and parasite is incomplete, and the gaps can largely be filled only in the laboratory. Some of the many problems that must be further studied in the experimental animal are the effects of various drugs on the schistosomes; the mode of entry of the parasites into the body, and the distribution of the parasites and of their eggs in the tissues; the comparative effects of exposing the uninfected and the infected animal to large numbers of parasites; the acquisition of immunity to infection; the

In the case of some other diseases the laboratory has provided answers to most of the biological problems that are raised by the host-parasite relationship. This is not the case with bilharziasis, where the laboratory has still an important part to play. In respect of the intermediate hosts, for example, much remains to be learned, and much can be studied in the laboratory, on such questions as the rate of their growth and sexual maturation; the effects on them of physical and chemical changes in the water in which they live; the degree to which some species and strains resist infection by the parasite;

3

manner in which immunity is acquired; the nature of the stimuli causing resistance; and the problem of inducing immunity.

Of the three main species of schistosome which cause disease, *Schistosoma japonicum* and *S. mansoni* are known to cause disease in other mammals as well as man. *S. haematobium* (2) in the natural state rarely infects any other species but man, and experimentally many species are resistant; but some primates, the hedgehog, and many rodents can be infected. For obvious reasons of economy, rapid breeding, and manageability, rodents are



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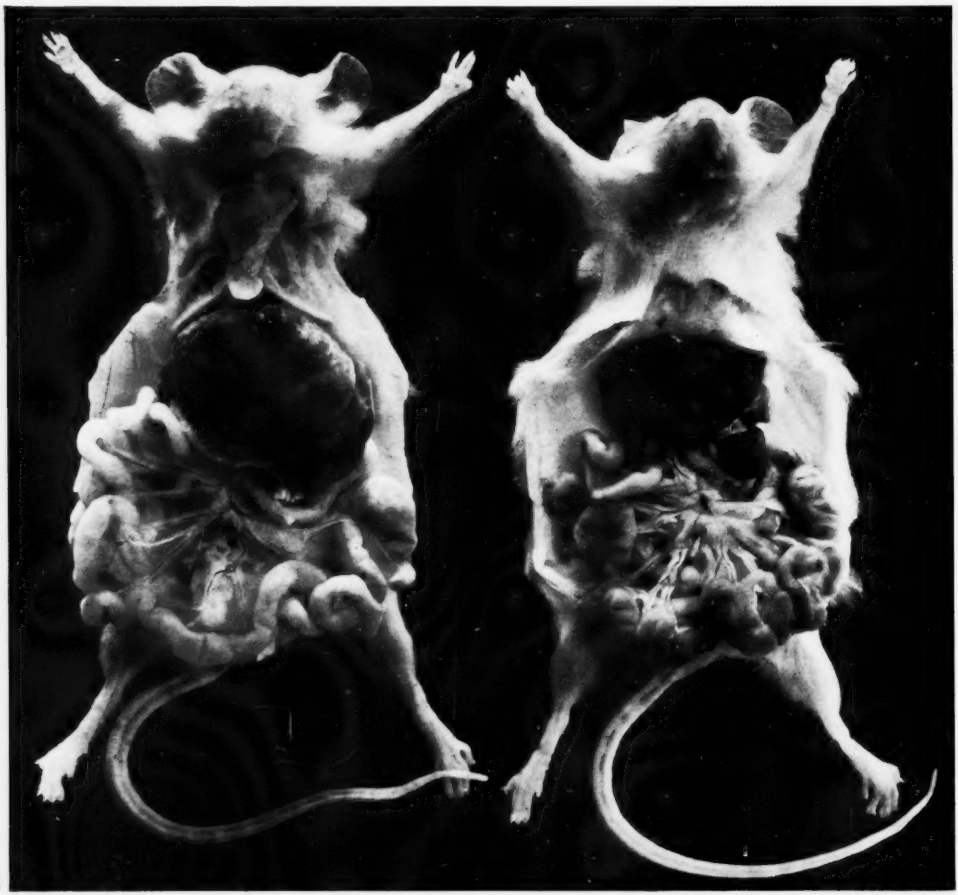
most used in the laboratory. They vary in their susceptibility to the disease, the most susceptible species in general use being the albino mouse and the golden hamster. In the case of *S. mansoni,* the situation is the reverse: relatively few species are totally resistant experimentally. Again, however, the albino mouse and the golden hamster are the laboratory animals *par excellence*, because of their extreme susceptibility and the high return of adult worms obtained from them.

Before treatment with parasiticidal drugs, the worms live mainly in the mesenteric or vesicular plexus of veins, the female enclosed in the gynaecophoric canal of the male. With treatment they relinquish their hold in the veins and are carried to the liver, where they are attacked and gradually invested by phagocytes. If the experimental animal is killed shortly after the beginning of treatment, the worm



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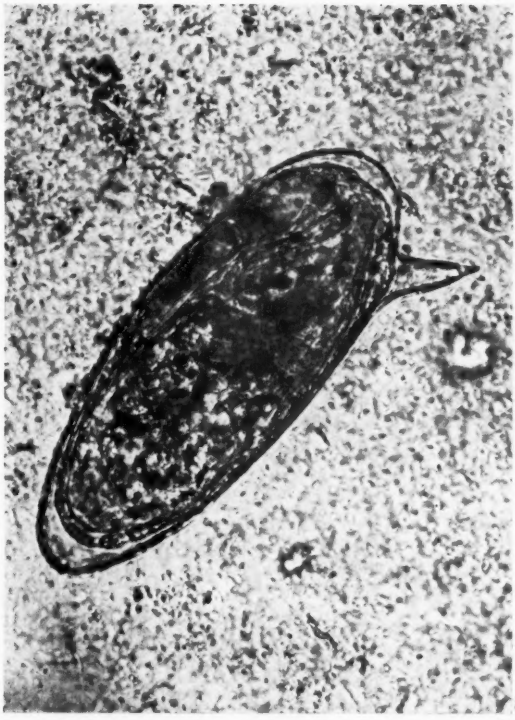
taken from the liver appears to be normal (**3**, left and **14**); if killed later, the outline is hazy, and the worm is seen to be invested by phagocytic cells (**3**, right). Phagocytosis is a gradual process, as can be shown (**4**) if worms are removed at intervals from the livers of infected mice undergoing treatment. Worms removed 18 hours after the beginning of treatment (A) are not as yet invested by phagocytes, and look normal, but they show reduced activity in Ringer's solution. In later specimens (B to E) investment with phagocytes gradually increases until it is complete, and the worm is slowly digested. If treatment is stopped prematurely the worms, although partially invested with phagocytes, regenerate and migrate back to the mesenteric or vesical plexus to resume egg-laying.

Dissection of a mouse 10 weeks after exposure to the cercariae will



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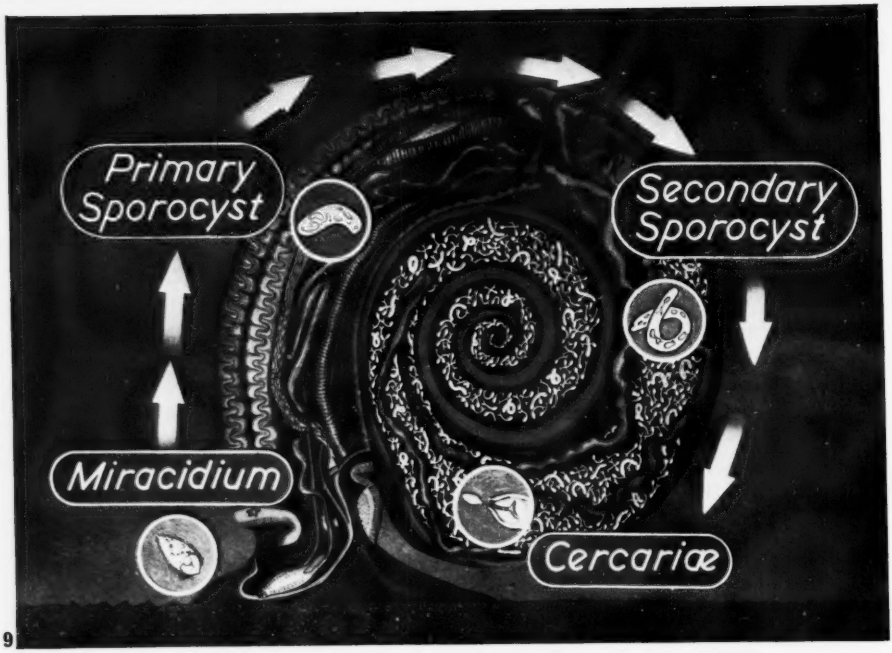

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show schistosomes in the mesenteric veins and a grossly enlarged liver and spleen (**5**). The presence of the worms in the mesenteric veins is indicated by the black pigment in the caeca of the females. The enlarged liver is studded with pseudotubercles formed by inflammatory tissue around eggs washed back in the portal blood; the spleen is also enlarged and infarcted (**6**, left). An uninfected mouse (**6**, right) has a

12

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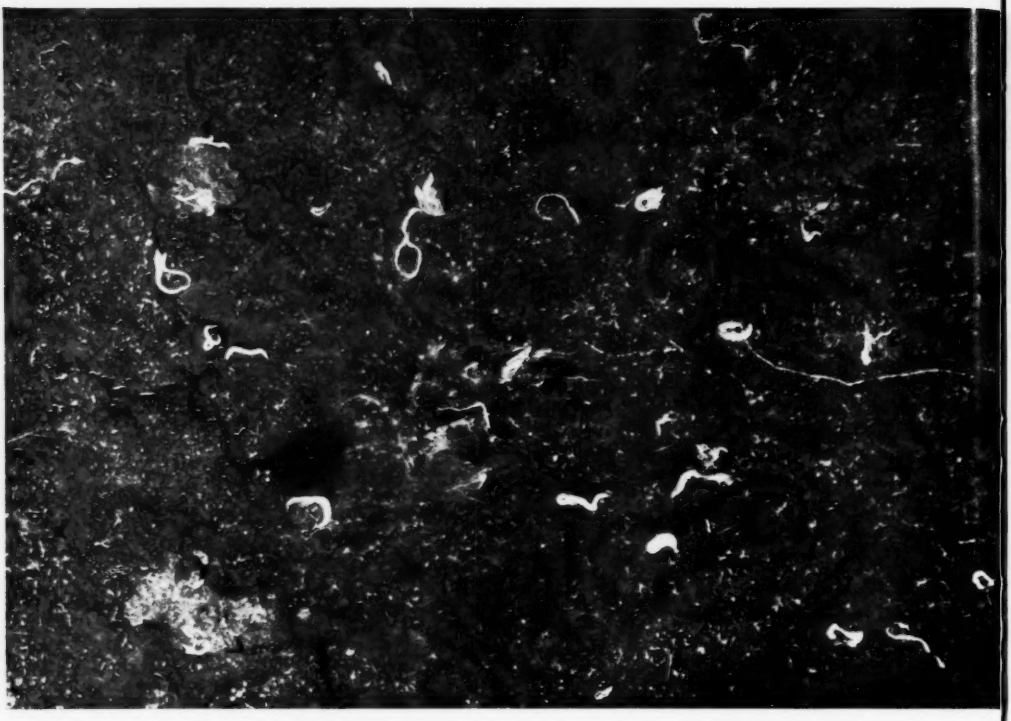


normal liver, and the usual small spleen. Mice which have been infected 10 weeks previously are at a suitable stage of development of the disease for experimental chemotherapy.

Not all of the many eggs produced by the schistosome escape from the body; in the case of *S. haematobium*, for example, only those which are laid in the venules of the bladder succeed in making their way into the lumen and so into the urine. Those which remain in the tissues give rise, by the inflammatory reaction they cause, to the pathological manifestations of bilharziasis. The disease is nevertheless finally diagnosed by the presence of the eggs in the urine or faeces, the eggs of the three main species each being of a characteristic shape; thus the egg of *S. mansoni* **(8)** is identified by its lateral spine. Within the egg the ciliated miracidium may be visible **(8)**, and motile. On contact with water the miracidium **(13)** hatches from the egg **(12)**, and it then swims about, propelled by its cilia and contractile movements, until it dies or finds a suitable intermediate host, a freshwater snail which in Africa is most commonly of the species *Biomphalaria* or *Bulinus*, in South and Central America of the genus *Australorbis* **(10)**, in the Western Pacific of the genus *Oncomelania*. Within the body of the snail the miracidium undergoes further transformations over a period of about six weeks (9), passing through primary and secondary sporocystic stages **(11)**, until its descendants, some 100 000-250 000 cercariae, are ready to emerge from the pulmonary cavity of the snail into the water **(7)**, and swim about, looking for a definitive host in which to complete their life cycle—a host which is still, in too many cases, man.

The World Health Organization acknowledges the valuable co-operation of the following institutions which have kindly made illustrations available for this article: Naval Medical School, National Naval Medical Center, Bethesda, Md., USA (1); Wellcome Laboratories of Tropical Medicine (2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14); Royal Society of Tropical Medicine and Hygiene (4).

MOLLUSCICIDES IN THE CONTROL OF BILHARZIASIS

The schistosome parasite responsible for bilharziasis can be attacked at various phases in its complicated life cycle. For immediate results, however, attention has been concentrated on methods of keeping in check the aquatic or amphibious snails that act as intermediate hosts for the parasite; this, in the opinion of the WHO Expert Committee on Bilharziasis, is the most important single method of preventing bilharziasis.[1]

There are various possible methods of controlling snails as well as by providing an unfavourable environment in an irrigation system. One is by the use of natural enemies or predators. Laboratory experiments have yielded valuable information about different species of animals which prey upon freshwater snails, but conditions in nature are frequently different, and not enough is known about the food preferences of these predators under natural conditions. Ducks, for example, were tried in the Philippines and found to be ineffective. Fish, toads, turtles, rats, crayfish, and other snails have all been considered and some tried, also without any apparent success. Even if a natural predator is found, it may well be that, as so often in nature, its activities would merely result in fluctuations in the numbers of predators and prey rather than in eradication of the latter.

Another possible method is by introducing parasites or diseases which would kill the snails. Here there is some information available on the parasites and diseases and on their effects on snail numbers; in this field, investigations should continue, as parasites and diseases are likely to be more specific in their action than natural enemies or predators. Snail colonies sometimes disappear for unknown reasons, however, and it may be concluded that much remains to be learnt about these vectors and about their habitats; until more is known these biological methods of control are more likely to be unsuccessful than otherwise.

Ecological methods of control have also been advocated. These include engineering methods to change the environment of the molluscan host, and alterations in agricultural practices. The widening and straightening of water courses, alternate drying and flooding of channels, drainage of low areas along streams, and cementing or covering of canals are all included in engineering methods. The cost of these methods is high, but it could in some circumstances, as at Leyte,[2] be to a great extent offset by the reclamation of the land and by increased production of rice and fish.

The most direct method of destroying snails is to treat their habitats with a chemical which is poisonous to them. The qualities desirable in a satisfactory molluscicide were enumerated in the first report of the WHO Expert Committee on Bilharziasis: "The chemical should at low concentration be toxic to snails and to their eggs in all stages; it should not be dangerously toxic to man, domestic animals, or crops; it should not be easily inactivated by physical or chemical means; it should be cheap; and it should be easy to handle."[3] Several thousand compounds have been screened for molluscicidal activity, but only a few have been found which satisfy the majority of these criteria, and none which can be considered ideal. A comprehensive list of the compounds, with an appraisal of their possibilities, will be found in the Expert Committee's report, and the subject has been reviewed again recently in the WHO Bulletin.[4]

Compounds in use

Many metallic salts and organic metal compounds are lethal to snails in low concentrations, but the majority of them are

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1953, **65**, 33

[2] See article on page 39.

[3] *Wld Hlth Org. techn. Rep. Ser.*, 1953, **65**, 33

[4] Paulini, E. (1958) *Bull. Wld Hlth Org.*, **18**, 975

too toxic to man and to domestic animals to permit their safe use. Copper sulfate is harmless, however, in concentrations that have a good molluscicidal activity and, as it is also readily available, it was one of the first compounds to be used on a large scale. It has been applied extensively in Egypt, Southern Rhodesia, the Gezira area of the Sudan, and to a smaller extent in the Belgian Congo, Venezuela and Brazil.

Unfortunately, copper sulfate suffers from two disadvantages: it appears to be ineffective against the eggs of the snails, and it is rapidly inactivated by adsorption on mud and colloidal particles, particularly in alkaline water, which precipitates the basic salt. This probably explains its transient action; when applied correctly under favourable conditions, it will produce an immediate, substantial reduction in the snail population, but the colonies quickly regain their original size.

Of the newer compounds, the halogenated phenols, their metallic salts, and the dinitroalkylphenols have given the most promising results. Dinitro-cyclohexylphenol proved very effective against *Oncomelania nosophora*, the molluscan intermediate host of *S. japonicum* in Japan. The vector snails of *S. mansoni* and *S. haematobium* are susceptible to the copper and sodium salts of pentachlorophenol. Sodium pentachlorophenate (NaPCP) has already been given extensive trials in Brazil, West Africa, Egypt, and Puerto Rico, and both the copper and the sodium salts are being used on a large scale for bilharziasis control in Venezuela. Besides being readily available and comparatively low priced, these compounds have the advantage that they destroy the eggs of the snails and are lethal to the cercariae, miracidia, and eggs of the schistosomes. Moreover, they seem to be less readily adsorbed by mud and silt than copper sulfate so that their action is more prolonged.

Obtaining maximum efficacy

It is obvious that the method of application of the molluscicide can influence its efficacy and that the most suitable method will vary to some extent according to local conditions. Trials carried out in Brazil, in which many different forms of application were compared, showed that " in general the application of the chemical in the form of briquettes or balls gave the best over-all results in running water." [5] Application in the form of a continuous drip was found useful under certain conditions, and spray pumps proved valuable for treating the banks of streams and for dealing with snails marooned by receding waters during the dry season. Most other methods were not found to be advantageous, and the application of NaPCP in the form of a dust was not considered advisable as it is a powerful respiratory irritant. However, a form of NaPCP recently marketed is claimed to be non-irritating.[6]

Perhaps even more important than the method of application of the molluscicide is the timing of the application to coincide with that period in its life-cycle when the snail can best be attacked. As the behaviour even of the same species of snail varies greatly from one region to another, it is important that thorough ecological studies should be carried out on the spot before commencing molluscicidal operations. In the case of *Bulinus truncatus*, for example, reproductive activity is at a maximum in July-August in Morocco and in September in Iraq. In Egypt, on the other hand, there are two peaks, one in April and the other in October-November.

Another important consideration is that in some areas the snails hibernate in winter —for example, during the winter closure of the canals in Egypt—while in others they aestivate when their habitats dry up in summer. It is of little value to apply molluscicides at these times, but experience indicates that: " It may be most favourable to treat after reflooding of a dried habitat, since reproduction of pulmonate vectors is generally rapid at that time, the population is small and the snails may be immature. " [7] In Brazil, where the molluscan hosts (*Australorbis glabratus* and *Tropicorbis centrimentalis*)

[5] Wright, W. H., Dobrovolny, C. G. & Berry, E. G. (1958) *Bull. Wld Hlth Org.*, **18**, 963

[6] Paulini, E. (1958) *Bull. Wld Hlth Org.*, **18**, 975

[7] *Wld Hlth Org. techn. Rep. Ser.*, 1957, 120

behave as if they were amphibious and aestivate during the dry season, NaPCP was found to be 100% effective in concentrations as low as 2 g per m^2 when applied immediately after the first heavy rain.[8] The significance of this finding is heightened by the fact that the few specimens that otherwise survive the drying up of their habitats in summer are able to repopulate the pools to their former density in 50-60 days.[9]

When a molluscicide is applied to an aqueous habitat, some of the snails may be protected from its action by the presence of vegetation or by sheltering in small bays, while others may escape exposure by climbing out of the water or burrowing in the mud. It is therefore advisable to remove dense vegetation before the application of molluscicide and to treat the banks of the watercourse as well as the water itself.

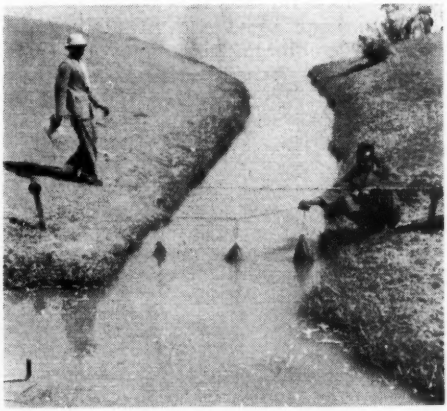
Reinfestation

One of the greatest problems in snail control is the prevention of reinfestation. As already mentioned, a few survivors can repopulate a habitat to its former density in a few months. But even if all the snails in a particular body of water can be annihilated there is always the risk that fresh ones will be brought in from an untreated habitat by animals or by aquatic birds.

A further complication is that snails or their eggs may be washed down from the higher reaches of a stream or from the main feeder canal into waters that have been treated. During a five-year pilot project with NaPCP being carried out at Warraq El Arab in Egypt,[10] it was observed that reinfestation of the canals regularly commenced when they were reopened in February after the winter closure and again during the period of the Nile floods. On each occasion, reinfestation has been promptly controlled by treating the main intake, the Sawahil Canal, with NaPCP and not a single snail has been discovered in the tertiary canals since the first treatment of the area in 1954. The success of these measures depended upon constant vigilance. A surveillance team of four trained men searched the area continuously, examining palm-leaf traps placed throughout the canals and drains, and frequently sieving the water with dip-nets. A search is being made for simpler methods of preventing reinfestation.

Chemical and mechanical barriers

In the Sudan, the use of a chemical barrier to prevent reinfestation of irrigation systems has been tried. After an initial application



Khaki drill bags, each containing approximately five kilograms of copper sulfate, suspended from a steel wire with pulleys stretched across a canal intake from a main canal. The gradual release of the molluscicide maintains a lethal concentration for a considerable time over a lengthy stretch of canal.

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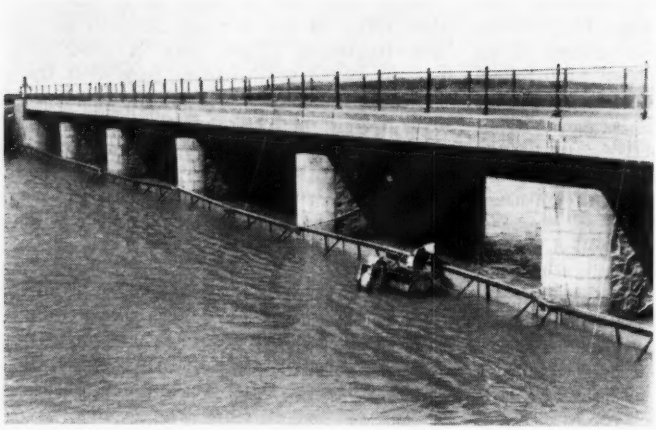
of copper sulfate in a concentration of 30 parts per million (p.p.m.), continuous sulfation of the water is carried out at the exit from the main canal, immediately before the inflow regulator giving access to the minor canals. At this point the current is sluggish,

[8] Wright, W. H., Dobrovolny, C. G. & Berry, E. G. (1958) *Bull. Wld Hlth Org.*, **18**, 963

[9] Barbosa, F. S. & Olivier, L. (1958) *Bull. Wld Hlth Org.*, **18**, 895

[10] Wright, W. H., Dobrovolny, C. G. & Berry, E. G. (1958) *Bull. Wld Hlth Org.*, **18**, 963



A general view of a mechanical trap designed to relieve pressure upon the chemical barrier. It consists of a series of fine-mesh galvanized iron screens fitted to rails stretching across the canal, and is cleared periodically by a worker who counts the snails caught in the debris before burning them.

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A closer view of a snail trap, on a smaller canal. The principle used is the same as in the picture above.

so that the snails remain for a longer time in contact with the molluscicide. A concentration of only 0.125 p.p.m. is claimed to be sufficient to kill the snails and at the same time to help control the growth of the aquatic weeds on which the snail normally breeds. Similar experiments in certain Mediterranean countries and in Kenya have also given encouraging results.

The use of traps placed across the entrance to the irrigation system is also being tried in the Sudan. An L-shaped trap, consisting of two wooden frames covered with a fine-mesh galvanized wire screen, is used. It is immersed in the water with half the vertical frame projecting above the surface and the horizontal frame pointing upstream. The vertical portion catches vegetation and debris floating downstream, while the horizontal portion prevents the material from being swept under the trap. It is claimed that the screen will hold up snails of all ages and sizes and will also retain the eggs, since the egg clutches are attached to vegetation which is caught by the screen. If the experiments are successful, such traps will provide a simple means of preventing reinfestation of the canals and greatly cheapen the cost of control.

Results of field trials

A recently reported trial with copper sulfate is the WHO-assisted bilharziasis control project in the Qalyub area of Egypt.[11] The quantity of molluscicide applied was calculated to provide a minimum exposure of 30 p.p.m. throughout the irrigation system. Over a period of two years, continuous surveys were carried out and fresh applications made whenever snails were discovered. Nevertheless, it was found impossible to keep the vectors away from the area for long. Immediately after sulfation, there was a very large reduction in the number of snails recovered in surveys, but at the end of a year they were again abundant everywhere: during the general spring survey, nearly half as many *Bulinus* snails were collected as in the previous year (before sulfation), and the number of *Biomphalaria* snails was almost unchanged.

Results with NaPCP have been more encouraging. Reference has already been made to the five-year pilot project at Warraq El Arab in Egypt. Three applications of NaPCP a year at a concentration of 10 p.p.m., and prompt re-treatment of the main drain at the first sign of reinfestation have kept the irrigation system free from snails for a period of three years. Furthermore, none of the snails recovered from the main canal during this time was found to be infected with *Schistosoma*, and it is therefore assumed that no transmission of bilharziasis has taken place. The accompanying table shows the steady fall in the infection rates for *S. haematobium* and *S. mansoni* in schoolchildren since the operations started.

In the spring of 1955, this project was extended to the contiguous Zumor Canal system, with the object of ascertaining to

[11] Van der Schalie, H. (1958) *Bull. Wld Hlth Org.*, 19, 263

PREVALENCE OF BILHARZIASIS INFECTION IN PRIMARY SCHOOLCHILDREN IN THE WARRAQ EL ARAB AREA, 1953-1956

Year	*Schistosoma haematobium*			*Schistosoma mansoni*		
	Number of children examined	Number positive	Percentage positive	Number of children examined	Number positive	Percentage positive
1953	1447	582	40.2	1437	72	5.0
1954	2582	989	38.3	2496	110	4.4
1955	2746	884	32.2	2657	79	3.0
1956	2750	713	25.9	2669	52	1.9

what extent a single treatment of a large primary canal with NaPCP would control snails throughout the area it serves. It had already been observed in the Warraq El Arab trials that a concentration of 10 p.p.m. of NaPCP was maintained for a distance of 22 km—the total length of the Sawahil Canal—and that six weeks after application a residual of 10 p.p.m. was still present in irrigation drains. In the Zumor Canal project, the molluscicide was introduced into the primary canal (the Giza Canal) at a point 14.5 km from the intake of the Zumor Canal; ten hours later a concentration of 10 p.p.m. had reached the secondary canals and after seventeen hours the concentration at a point 30 km from the point of application was still 10 p.p.m. Unfortunately, temporary dams thrown up by farmers and certain other factors, such as the direction or velocity of flow, prevented a few of the secondary and tertiary canals from receiving an adequate dosage. With these exceptions, however, complete eradication of the snails was obtained throughout the entire system, involving 1800 km of canals and drains.

A team similar to that which was responsible for these two trials in Egypt has also demonstrated the efficacy of NaPCP against *Australorbis glabratus* and *Tropicorbis centrimentalis* in Brazil.[12] Although a single application failed to kill the entire snail population in every stream, no living snails were found for a period of 2 months in 75% of the streams where the concentration and dispersion of the chemical were adequate. In some of the streams, freedom from snails was maintained for periods up to 12 months, and in 40% of the streams surveys conducted after 4 months showed that the snail population was still less than 10% of its initial size. It must be remembered that these were only preliminary trials designed to provide information on the required dosage, exposure time, most feasible methods of application, etc. Consequently, the methods used were not always the most efficacious ones.

[12] Wright, W. H., Dobrovolny, C. G. & Berry, E. G. (1958) *Bull. Wld Hlth Org.*, **18**, 963

Cost

In considering the cost of snail control operations, the long life of the schistosome parasite in the human host has to be borne in mind. Even if all the snails in a particular area were eliminated, a human reservoir of infection would remain for several years, and throughout this period snail control measures would have to be continued to prevent reinfestation. On the other hand, the cost must be balanced against the economic advantages arising out of the improved health of the community. Van der Schalie [13] estimated the cost of copper sulfate treatment of approximately 300 km of canals and drains in the Qalyub area of Egypt at $14 200—a figure which he considered prohibitive. In the Warraq El Arab project, which covered a population of 50 000, the cost of NaPCP used for 182 km of canals and drains was $4147. The team estimated that copper sulfate treatment applied only to those sections of the system where snails were found would have been almost twice as expensive. It would seem that if NaPCP is applied in the most effective manner, its use on a large scale for the control of snails in irrigation systems will prove a practical and economic proposition, particularly if it can be used in combination with suitable barriers to prevent reinfestation of the canals. But this presupposes that before major programmes are undertaken adequate studies are carried out on the ecology of the molluscan intermediate hosts, the nature of the terrain, the physical features of the water course, and the types of vegetation. Only when all this information is available is it possible for the application of the molluscicide to be correctly timed, the dose-rate/time-factor to be accurately determined, and the appropriate method of application to be selected. It is the aim of WHO to encourage this methodical approach to the use of molluscicides while at the same time sponsoring basic research on snail ecology that may lead to new methods of control.

[13] Van der Schalie, H. (1958) *Bull. Wld Hlth Org.*, **19**, 263

THE LEYTE BILHARZIASIS PROJECT

Bilharziasis due to infection with *Schistosoma japonicum* was first reported from the Philippines in 1906. Although sporadic studies of the disease were made there during the succeeding forty years, little was done towards the institution of control measures. Research was given fresh impetus, however, by outbreaks of bilharziasis which occurred in 1945 among American and Australian armed forces stationed on the islands. It soon became apparent that the problem was of considerable magnitude and the Philippine Government decided on prompt action. In 1951, a Division of Schistosomiasis was created within the Department of Health, and the following year the Government requested WHO to send a team of consultants to study the bilharziasis problem in the Philippines. The team recommended the concentration of funds and efforts on a pilot project of 3-6 years' duration, to be carried out in parts of the island of Leyte, which appeared to be the most important endemic area.[1]

The Philippine Government acted quickly on these recommendations, and with the assistance of the Foreign Operations Administration of the USA and the Philippine Council for United States Aid, a fully equipped project building, including laboratories, was constructed and staffed. Three members of the project staff were experts provided by WHO. By June 1953, the project was ready to start functioning officially.

Synopsis of the project

Until 1953, bilharziasis in the Philippines had been attacked almost entirely by medical methods. There is little evidence, however, that drug treatment can play a significant part in the control of the disease, except perhaps in the final stages of a campaign. In Egypt it has already been practised for years without significantly affecting the prevalence of bilharziasis there. Not only is cure uncertain, but reinfection almost invariably occurs. Moreover, most bilharziasis patients are undernourished and have two or more other helminthic infections as well—a situation that militates against the successful use of the drugs at present available.

The cycle of infection must therefore be interrupted at some point outside the human host. The principal aims of the project were to find answers to the complicated biological and social problems that this involves.

Man contracts bilharziasis through contact with waters harbouring infected vector snails, and the snails become infected because their habitats are contaminated by human or animal excreta containing schistosome eggs. The provision of latrine facilities would thus appear to be a suitable method of control, but before the value of this measure can be decided it is necessary to know the relative importance of man and of animals as reservoirs of infection. An epidemiological survey conducted by the project team indicated that humans are the main source of infection in the area. However, an attempt to provide latrines for the entire population of one village revealed the difficulties of such an undertaking. Apart from the considerable cost of the scheme, the team encountered great reluctance on the part of the population to use the facilities provided.

An approach that would eradicate bilharziasis if it could be successfully applied is elimination of the vector snails. This is not as simple as it might appear at first sight, however. Molluscicides are never 100% effective and the survivors rapidly repopulate the habitat. It is necessary to bring about some permanent change in the habitat that will render it incapable of supporting a snail colony. But the factors that make one stretch of water suitable for snails and a neighbouring one unsuitable are elusive.

[1] *Bull. Wld Hlth Org.*, 1958, 18, 345, 481; 19, 223

On the other hand, such drastic measures as draining or filling in habitats may prove too expensive to be applied on a large scale. For these reasons, the project team undertook a comprehensive ecological study of the snails, designed to reveal the most vulnerable stages in the life cycle and the principal factors in the environment on which the continued existence of the snails depends. An investigation was also made into the exact part played by the snails in the transmission of the disease, with particular reference to the effect of rainfall, temperature, sunlight, etc. on their infectivity.

Although measures designed to change the habitats of the snails are expensive, they may become economically feasible if they can be made to yield some other return, such as improved use of the land for agricultural purposes. This aspect of control was also investigated by the team, with very promising results. It was found, for example, that improved methods of rice farming would not only greatly reduce the snail population of the rice-fields, but also double the yield of rice.

The data assembled from these studies will enable a systematic approach to be made to the problem of bilharziasis control in the Philippines, and at the same time provide a base-line for the future evaluation of the progress achieved. Furthermore, the project may well serve as a model for other countries facing the problem of bilharziasis control: although the results are not necessarily transferable directly to other areas, where the vector snails and the environmental and social conditions may be different, the approach is universally applicable.

The project areas

The island of Leyte lies at the centre of the Visayan group of islands in the Philippines. Of the island's total area of approximately 2800 square miles (7200 km^2), nearly 75% consists of rough mountain and rolling upland (Fig. 1). To the north-east, however, there is a long stretch of plain, constituting about one-sixth of the total area of Leyte. This plain is crossed by numerous perennial rivers which often flood in the rainy season; the soil drains poorly, resulting in vast swampy areas. The climate is warm and humid, with abundant rainfall throughout the year. Conditions are favourable for the development of vector snails and bilharziasis is endemic in this area. By contrast, western Leyte, which is slightly drier and is well drained, is free from the disease.

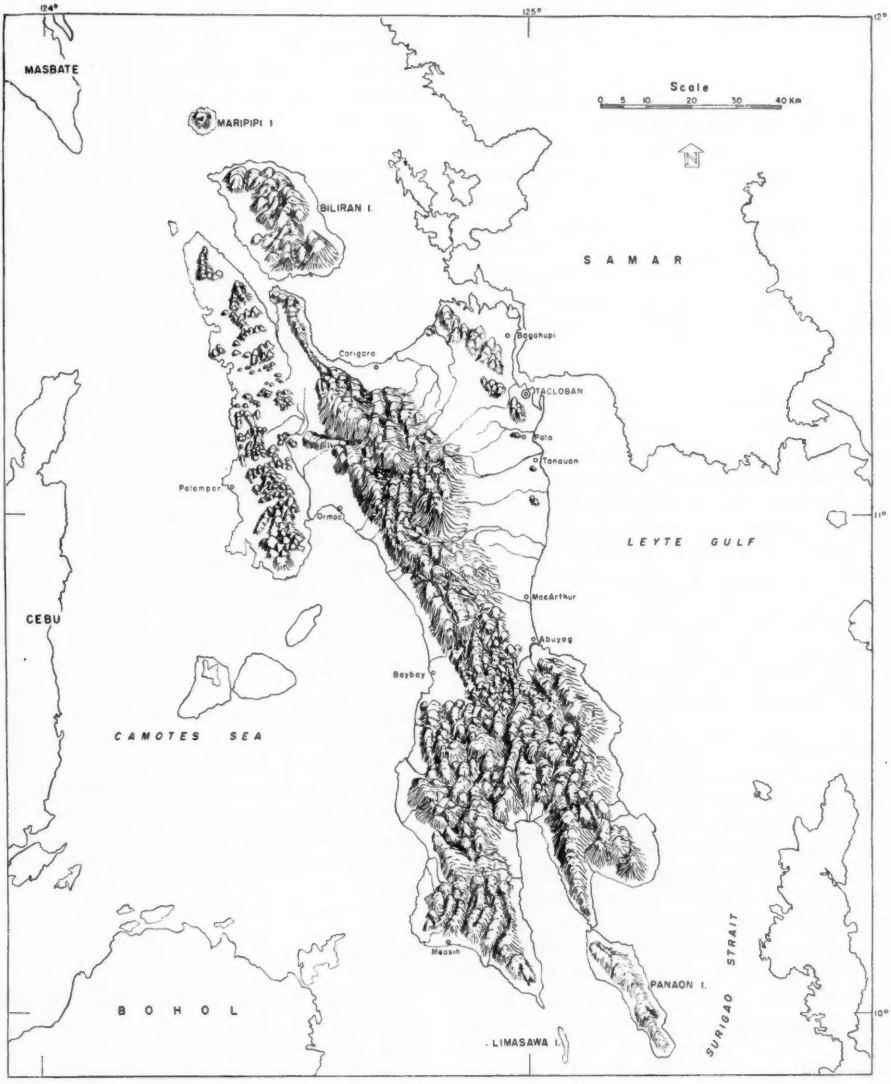
The main areas selected for the project lie around Palo and the neighbouring municipality of Tanauan, with the headquarters at Palo, 12 km south of the capital city of Tacloban. Conditions there are being compared with those at Carigara on the northern coast, which was originally thought to be entirely free from bilharziasis. Some caution may be necessary in interpreting the findings, however, as a few cases of the disease were discovered there during the survey. Following completion of the preliminary studies, it is intended to institute an energetic programme of community development in the newly opened-up area of Bagahupi, 30 km north of Palo. This programme will incorporate all the methods of control which have been developed.

Poblaciones and barrios

Each of the four localities mentioned above constitutes a municipality, of which there are 60 in the whole province of Leyte. Each municipality consists of a central area, known as the " población " surrounded by 10-20 " barrios " or villages. The población is urban or semi-urban in character and includes the municipal offices, church, market place, school, and health centre. It accounts for about 20% of the total population of the municipality. The barrio is the smallest recognized unit and constitutes the primary social group.

Until 1954, many municipalities were without health or medical care and such services as existed were limited mainly to the población; the barrios received almost no benefit. Under the new Rural Health Act passed in 1954, the position of provincial health officer was created, and a municipal

FIG. 1. RELIEF MAP OF LEYTE PROVINCE, PHILIPPINES



health officer was appointed for each municipality. Preventive and out-patient care are now under one health unit, consisting of a physician, public health nurse, midwife and sanitary inspector. By 1956, 39 fully staffed health units were in operation in Leyte, and complete coverage was planned for 1958. Unfortunately, attendance at the rural health centres has so far been small in comparison with the population served; plans are being made for the municipal health officer to hold clinics at suitable centres in the barrios by rotation each week. According to the 1954 annual report of the Leyte Provincial Health Officer, 95.5% of deaths in Leyte occur unattended by a physician. The people of the barrios believe that illnesses are caused mainly by evil influences, and have much faith in the local " herbolarios ".

Living conditions

The population of Leyte has been increasing at the rate of about 2% per year for the past half-century and the population density is now nearly 325 per square mile (125 per km²). Housing is extremely simple and nearly all houses are constructed of locally available materials, such as bamboo, nipa palm, and cogon grass. To avoid floods, the houses are set on stilts. Only about 12% of the population have latrine facilities of any kind. The rest of the barrio people defecate in the open, pigs often acting as ready scavengers. There is no system of drainage anywhere; even in the larger towns there are only concrete surface-drains which become stagnant cesspools and breed mosquitos. The situation is made worse by the heavy rains and by the decaying vegetation which surrounds the houses. But, in spite of these unhygienic conditions, the people are remarkably clean, changing, washing and ironing their clothes with great frequency even in the remotest barrios. Water is usually obtained from sanitary dug wells or improved springs. These supply 55% of the population. Only 22% have piped water or water from artesian wells, while 23% have water from unprotected sources.

The census

A complete census was undertaken in the four project areas of Palo, Tanauan, Carigara and Bagahupi, which were each subdivided, on the basis of apparent topographic and demographic differences, into three divisions: the " población ", the " coastal " division, and the " inland " division. The information collected included the total population, with age and sex composition, the number of houses and the number of families. From these figures it was possible to calculate the number of persons per house, the percentage of the population under 20 years, and the proportion of males to females. Information was also collected on the main occupations, the number of animals per house, and the number of houses with latrines. A summary of the data will be found in Table 1.

To permit an assessment of the part played by animals in the transmission of bilharziasis, a census of the animal population was also taken. On the average, there were nearly three animals per household. In all three divisions of Palo and in the costal and inland divisions of Tanauan there was approximately one pig to each house and one dog to every other house. In the población of Tanauan, there were roughly three pigs and one dog to every house. Carabaos (water buffalo) averaged about one to every two houses in Palo and three to every four houses in Tanauan. Cats were in almost the same proportion. Goats, cows and horses were kept much less frequently, especially in Tanauan. Attempts to determine the rodent population were unsuccessful, but on the basis of experience in comparable areas elsewhere, a figure of ten rodents per person seemed a reasonable working assumption.

Techniques

For the studies in Palo and Tanauan, approximately 20% of the population in each age-group was selected, so that the age-structure of the sample was the same as that of the total population. At Carigara and Bagahupi, random samples were ob-

TABLE I. SUMMARY OF CENSUS DATA FOR PALO, TANAUAN, CARIGARA AND BAGAHUPI

Town	Number of houses	Number of families	Population	Number of persons per house	Percentage of population under 20 years	Proportion of males to females	Main occupation	Number of animals per house	Percentage of houses with latrines
Palo	2 832	2 876	14 819	5.2	53.0	93:100	Men : farmers, unskilled labourers and jobless Women : housekeeping	2.7	50.3
Tanauan	2 707	2 753	12 081	4.5	50.2	102:100	Men : farmers, fishermen and jobless Women : housekeeping	3.5	20.8
Carigara	2 857	2 903	15 346	5.4	55.0	97:100	Men : farmers, fishermen and jobless Women : housekeeping	2.6	25.1
Bagahupi	142	143	822	5.8	58.7	108:100	Farmers and jobless	2.3	14.1

tained by choosing individuals from every tenth or every fifth house in the community.

Stool examinations were carried out on 5-cm³ specimens within three hours of collection, using a combination of the following techniques:

1. One direct faecal smear (2 cover-slip preparations).

2. Glycerol sedimentation using 0.5% glycerol in tap water and examination of the entire sediment.

3. Hatching the eggs in the sediment from 2.

4. Examination of the sediment from 3.

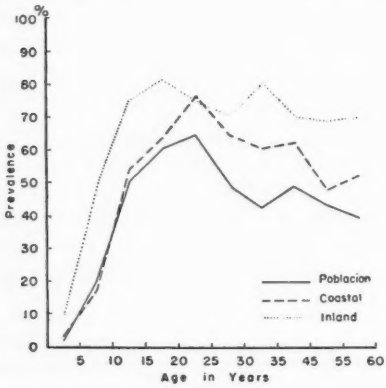
This standard method was found to be superior to other methods tried, with the exception of the MIFC (merthiolate-iodine-formaldehyde concentration) technique, which was also used in some circumstances. However, the standard method has the advantage that it allows observations on the viability of the eggs, and that it can be performed away from an equipped laboratory as it requires fewer chemicals and no centrifuge. For quantitative determinations of the number of eggs in the stools, two methods were used: the Stoll technique with 3 ml of faeces, and the MIFC egg count in total sediment, using 1 ml of faeces. The Stoll technique was found more efficient for counting the eggs of intestinal helminths, whereas the MIFC technique was superior for schistosome eggs.

The reliability of the intradermal test previously used in mass-screening surveys for *S. japonicum* infection was also evaluated. The results showed that although the test does not provide evidence of active infection with bilharziasis, it is of value as a rapid screening method. The degree of sensitivity increases with age. Infection in children may therefore be missed, but in adults up to 90% of cases can be detected.

Prevalence of bilharziasis in the pilot areas

Of the total of 2909 persons examined in the Palo area, 48% were found to be infected with bilharziasis. As can be seen

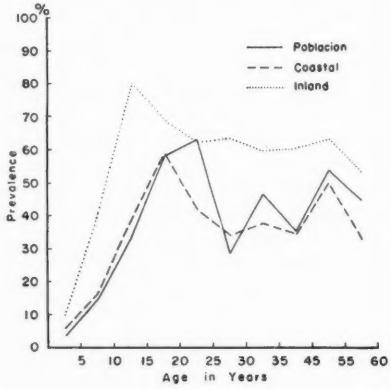
FIG. 2.
AGE PREVALENCE OF SCHISTOSOME INFECTION IN THE THREE DIVISIONS OF PALO, 1953-54



from Fig. 2, the infection builds up rapidly during childhood and adolescence, reaching a peak in the age-group 20-24 years, with a prevalence rate for the whole area of 71.1%. Significant differences were observed between the población, the coastal division, and the inland division. In the inland districts, prevalence increases more rapidly with age, and the peak is reached in the age-group 15-19. The higher prevalence is maintained throughout all the age-groups. The población and the coastal areas do not differ appreciably with regard to age prevalence until the peak is reached at 20-24 years, but thereafter the coastal division occupies an intermediate position between the inland division and the población. These differences can be explained partly on the basis of environmental factors, partly on the basis of occupation. The inland division has the poorest sanitation of the whole Palo area, and the housing and living conditions are also backward compared with the other two divisions. The población, in turn, has a more urban character and better sanitation than the coastal division. The occupations that bring people most in contact with infected waters are farming and inland fishing; seagoing fishing brings less risk of infection. The population of the población is made up mainly of small businessmen, municipal employees, farmers and a few carpenters; in the coastal division, the main industry is fishing, combined with some lowland rice growing; while in the inland division, lowland rice farming is the main industry.

The prevalence of bilharziasis in the Tanauan area was very similar to that in Palo: of 2246 persons examined, 46.3% were found to be infected. The age prevalence rates (Fig. 3) also show the same general trends as those for Palo, but the initial rise is much steeper and the peak is reached sooner (in the age-group 10-14 for the whole area).

FIG. 3.
AGE PREVALENCE OF SCHISTOSOME INFECTION IN THE THREE DIVISIONS OF TANAUAN, 1953-54



The difference between the inland division and the other two divisions is again well marked, but the población and the coastal division have very similar age prevalences. This is explained by the fact that in Tanauan the población is itself situated on the coast. The occupational differences observed in Palo were also found in Tanauan.

As already pointed out, Carigara was originally included in the area in the belief that it was entirely free from bilharziasis. In fact, no cases were detected among the 500 people examined in the población, but

9 were found in the coastal barrios and 35 in the inland barrios out of 1156 persons examined. The total of 44 cases represents a prevalence of only 2.7%, and it is not certain whether these were indigenous cases or imported into Carigara from neighbouring areas in the endemic valley. At all events, Carigara can be regarded as at least a hypoendemic area, and with due precautions the findings there can be used to throw light on some obscure points in the epidemiology of the disease in Palo.

In the barrio of Bagahupi, the only known endemic area north of Tacloban, 177 persons were examined and an over-all prevalence rate of 43% was found, with a maximum of 69% in the age-group 20-24 years. Rates were highest (over 50%) in farmers, tubagatherers and the "jobless".

Prevalence of common helminthic infections

The high prevalence of common helminthic infections in hot countries often masks the epidemiological features of bilharziasis and makes it difficult to assess its public health significance. The team therefore deemed it useful to search for other intestinal worms at the same time as the stools were examined for schistosome eggs.

In all four of the pilot areas, infection with one or more of the three common parasites—*Ascaris*, *Trichuris* and *Ancylostoma*—was found to be present in 98-99% of the persons examined. As might be expected, *Ascaris* and *Trichuris* infections were acquired at an early age and the prevalence of both diseases attained a peak of over 90% in the age-group 5-9. Subsequently, the prevalence of *Ascaris* infection showed a downward trend, whereas that of *Trichuris* infection remained constant through all age-groups. *Ancylostoma* infection had a relatively low prevalence in early childhood, but about 70% of children were infected by the age of 10-15 years, and the prevalence continued to increase slowly with advancing age. Despite the differences in living conditions and sanitation between the población, the inland and the coastal divisions of the municipalities, there were no marked differences between them with regard to the prevalence of helminthic infections. The conclusion was drawn that, although proper sanitation is of undoubted value in preventing the spread of helminthiases, "pin-point" sanitation can have little effect when the sanitation elsewhere in the area is of a low order. This does not mean that improved sanitation, however limited in scope, should not be encouraged.

The public health significance of bilharziasis

In 1953, the WHO Expert Committee on Bilharziasis [2] pointed out that the proportion of persons infected with *Schistosoma* who show clinical signs of the disease appears to vary considerably from country to country and that the cause of these variations is not at present thoroughly understood. In the Leyte project, an attempt was made to obtain a fairly accurate assessment of the amount of disease and disability caused by *Schistosoma* infection. This was by no means a simple undertaking. As already pointed out, 95.5% of deaths in this area occur without medical attendance. Cause of death statistics are therefore valueless. The only possible approach was through morbidity studies, and as the main object was to establish the degree of disability, the following classification was decided on:

I. *Mild*: occasional abdominal pain, occasional diarrhoea or dysentery; no absence from work.

II. *Moderate*: as I, but with anaemia or weakness; inability to do hard work.

III. *Severe*: as II, but with recurring attacks of diarrhoea and dysentery; frequent absences from work.

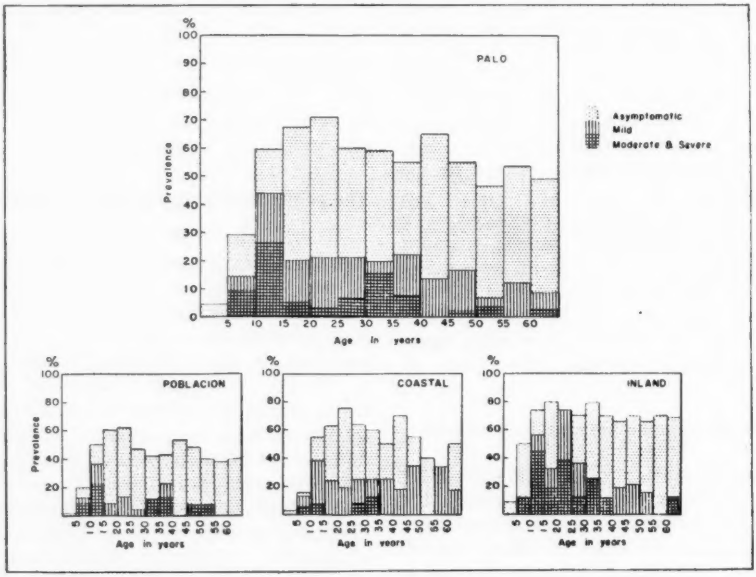
IV. *Very severe*: as III, but with ascites or emaciation, or both; total inability to work.

On the basis of a preliminary pilot study, a 20% sample was selected from all stool-positive cases in the Palo area, the selection being made by reference to a table of random

[2] *Wld Hlth Org. techn. Rep. Ser.*, 1953, 65

FIG. 4.

CLINICAL GRADIENT OF SCHISTOSOME-INFECTED INDIVIDUALS IN PALO AND ITS THREE DIVISIONS



numbers. The persons so selected were visited in their own homes by two members of the project team, who made a careful record on a standard form of the past and present history and the findings of physical examinations. Haemoglobin was determined and a box left for the collection of a stool sample the following morning. With a few exceptions, co-operation was excellent.

Of the 278 infected persons examined, 105 showed clinical evidence of bilharziasis, but none of these cases were classified as "very severe" and only 4 as "severe". More than half the cases (60) were classified as "mild" and the remaining 41 as "moderate". In terms of the total population, this would mean that 10.3% have mild symptoms, 7% have moderate symptoms, and 0.7% have severe symptoms. Clinical symptoms were found to occur most commonly between the ages of 10 and 14; in this age-group, 73% of the infected children had manifest symptoms referable to bilharziasis, and the proportion of moderate and severe cases was also higher than in the other age-groups. No significant sex differences were found. These results (Fig. 4) show clearly that children in the 10-14 years age-group bear the brunt of the disease and that a large proportion of infected persons are able to live in a state of natural balance with the parasite without any profound disturbance in their normal life.

Hepatomegaly

As liver enlargement is very common in the area even in the absence of bilharziasis, it could not be used as an index of the severity of the disease. Nevertheless, it is in the liver, more than in any other organ, that pathological changes are to be found in bilharziasis caused by *S. japonicum*. A separate record of liver enlargement was therefore made in all cases where physical examination was not refused. To obtain an

accurate estimate of liver size, the team divided the abdominal wall between the costal margin and the umbilicus into six segments by two horizontal planes—one midway across the epigastrium and one at the level of the pylorus—and by one vertical plane passing through the umbilicus.

The liver size was denoted as 0.5 if it projected into one segment, as 1 if it projected into two segments, and so on. No livers projecting below the umbilical plane, i.e., larger than size 3, were found. The liver rate—percentage of livers palpable below the costal margin—was highest in the age-groups 5-9 and 10-14 (78 and 67 respectively). From 15 years of age onwards the rate remained between 20 and 30. Liver size reached a maximum in the 10-14 years age-group. No significant differences were found between males and females, either with regard to liver rate or to liver size. The liver rate in the coastal division—the division with the highest percentage of mild cases—was significantly lower than in the inland division or the población. The results suggest that, in spite of the presence of many complicating factors, there is a definite correlation between hepatomegaly and the severity of bilharziasis infection.

Incidence of bilharziasis in the age-group 5-9

Data on prevalence—the percentage of the population exhibiting infection at a given time—do not reflect differences between diseases with a high incidence but a short duration and those with a low incidence but a long duration. On the other hand, changes in incidence provide a sensitive index of the efficacy of control measures. For this reason, the team also undertook a " longitudinal " study on children in the age-group 5-9 years to determine the actual incidence of bilharziasis.

The study was made on a random sample of 200 children taken from a group of 407 children who had been found to be free from bilharziasis during a prevalence survey two years previously. In the course of house-to-house visits, physical examinations, haemoglobin estimations, eosinophil counts and stool examinations were made. The mothers of the children were also interviewed. A child was regarded as negative on the basis of three consecutive negative stool examinations by the MIFC technique. The study showed that 70 children had acquired the infection during an average time interval of 22 months, giving an annual incidence rate of 20.4%. The incidence in the población was 12%, in the coastal division 11%, and in the inland division 46%. Moreover, in the inland division 32% of the new infections were in children under 7 years old, compared with 13% in the población and 8% in the coastal division. This is in accordance with the varying opportunities for infection provided by the different environments, as already reflected in the findings on prevalence.

Transmission of *S. japonicum* infection

Many domestic animals and other mammals have been shown to be capable of harbouring *S. japonicum*, so that the parasite has a wide choice of hosts in nature. In order to develop a rational control programme, it is necessary to know the relative importance of the different reservoir hosts in the transmission of the disease.

The seven mammals known to be concerned in the transmission of bilharziasis in the Leyte area are man, pigs, dogs, goats, carabaos, cows, and rats. The numerical strength of each of these hosts was already known from the census conducted at the beginning of the survey. By examining stool samples, the team determined the prevalence rates for the various hosts, the mean daily egg output, and the hatchability of the eggs—the percentage of eggs producing miracidia. The product of the mean daily egg output and the hatchability gave the mean daily production of miracidia, and when this was multiplied by the number of persons or animals infected a " transmission index " was obtained. The results are shown in Table 2, the last column of which gives the " relative transmission index " calculated as a percentage. Although around 10 times as many eggs per day are produced in dogs, cows and carabaos as in

TABLE 2. RELATIVE TRANSMISSION INDEX OF DIFFERENT HOSTS OF *SCHISTOSOMA JAPONICUM* IN PALO

Host	Population	Prevalence (%)	Mean daily egg output	Hatchability (%)	Mean daily miracidia produced	Transmission index	Relative transmission index (% of total)
	A	B	C	D	C × D	(A × B) × (C × D) ×	$\frac{(A \times B) \times (C \times D)}{(\Sigma)} \times 100$
Human	14 819	48.0	1 123	42.4	476	3 385 845	75.7
Dog	1 517	18.2	13 106	17.8	2 333	644 127	14.4
Cow	76	38.2	12 212	71.9	8 780	254 901	5.7
Pig	3 193	13.3	481	31.9	153	64 974	1.5
Rat	148 190*	22.7	21	10.6	2	67 278	1.5
Carabao	1 318	1.5	9 166	29.4	2 695	53 280	1.2
Goat	204	1.4	952	71.4	680	1 942	0.04
						Total (Σ) 4 472 347	

* Estimated number of 10 rats per person, which equals 60 rats per hectare

humans, the hatchability of the eggs from dogs and carabaos is relatively low. Moreover, there are only 76 cows in the whole Palo area. Consequently, the transmission index for man is more than 5 times that for the dog, more than 13 times that for the cow, and more than 50 times that for any of the other mammals. It is thus clear that humans constitute the main source of infection in this area. An analysis of the figures for the human population by age-groups showed that almost 60% of the total infection comes from children aged 10-14 years, the age-group which had already been shown to bear the main brunt of the disease. The findings demonstrate the importance of the sanitary disposal of human faeces and the need to concentrate medical care and public health measures on the age-group 10-14. At the same time, it is evidently essential to keep a check on the cow and dog populations in the endemic areas.

The snail vector

In 1932, Tubangui identified the intermediate host of bilharziasis in the Philippines as *Oncomelania quadrasi*. Although snails of the genus *Oncomelania* act as intermediate host for *S. japonicum* in several countries of the Western Pacific area, the species *O. quadrasi* has not so far been reported outside the Philippines. Even here its distribution is very limited and it appears to be confined almost entirely to the islands of Mindanao and Samar and to eastern Leyte. These are all characterized by the absence of a dry season. Most of the snail habitats are found near sea level, but whatever their elevation they are always very flat, a feature that makes for retention of water.

In all the areas inhabited by *O. quadrasi* there occur meandering, sluggish streams, densely populated with snails; numerous small " swamps ", formed by seepages or springs emerging at the foot of high, steep banks, also support snail colonies. Both the streams and the " swamps " are used for fishing and as carabao wallows. During road construction work, rather large ditches are often left at the sides of the road, and these, too, provide good habitats for *O. quadrasi*.

A comparison of the various habitats of *O. quadrasi* reveals some striking differences, but one feature they all have in common is that they never dry out for any length of

time. A certain amount of water and a relatively undisturbed situation appear to be necessary for the snails to thrive. But there are some places that apparently have the necessary moisture, topography, and vegetation, yet do not support snail colonies. Soil and water analyses failed to reveal any consistent differences between these areas and those that supported snails, nor could any regular differences be found in the fluctuations in water levels.

Habits of *O. quadrasi*

In order to obtain a complete understanding of the ecology of *O. quadrasi*, the team made a detailed study of its behaviour and activity. Observations were carried out continuously over 24-hour periods; copulation, movement and climbing were observed in the field, and feeding and egg-laying in the laboratory. The areas for observation of movement were marked out by means of metal frames, 18 cm square, placed on the ground at three different sites in the colony. The sites were so chosen that not more than 10 snails were included within any one frame. For observations on copulation, larger areas, 50 cm square, were staked out. All forms of activity were greater at night than during the day, and this applied especially to copulation. The percentage of snails copulating was highest at 10.00 p.m. (5.2%) and lowest at 10.00 a.m. (1.4%). The pattern of activity was affected by the weather, however, and on a rainy afternoon 4.3% of the snails were observed *in copula* as early as 2.00 p. m., normally the time of least activity. From observations on the duration of copulation, it was computed that, on the average, snails copulate once a day.

The influence of humidity, temperature, light and atmospheric pressure was investigated more closely under laboratory conditions. It could be easily demonstrated that the reaction to light is one of avoidance. During the day this would produce considerable horizontal movement as the snails crawl in search of shade, but would restrict climbing, an effect that would be reinforced by the lower humidity away from the surface of the mud. At night, increasing humidity would more or less counterbalance the effect of darkness and lowered temperature and at the same time encourage climbing and copulation. Similar considerations may account for the seasonal differences observed, for example, that copulation is less frequent in June, when the weather is dry and the days are long, than it is in September, the beginning of the rainy season.

Another observation was that the snails laid nearly three times as many eggs at night as during the day. On the other hand, feeding was more rapid during the day than at night. It would appear that the activities that are more pronounced at night are those relating to reproduction, climbing probably representing a form of mate-seeking.

The team concluded from several series of observations that about 88% of the eggs laid by snails are hatchable, but the mortality of the young snails is high, less than 20% surviving to adulthood. When they first emerge, the snails are aquatic and during the first two weeks of their existence spend most of their time below water. More than half of them die during this aquatic stage.

Density of snail colonies

Changes in the density of a snail population and in the age and sex structure provide a ready index of the efficacy of control measures and of whether or not active breeding is taking place.

To obtain an accurate estimate of the density, a large number of small samples must be taken, scattered as widely as possible over the area. The routine method of sampling used by the team was to decide in advance on a pattern of evenly spaced sampling sites and then to drop a metal ring, 13.5 cm in diameter, over each of these sites. All the snails that could be found within the ring were picked up with forceps and placed in a numbered envelope. At least 30 samples were taken before drawing conclusions about the population. The method of ring sampling is impossible, however, where the water is more than 5 cm deep, and it is

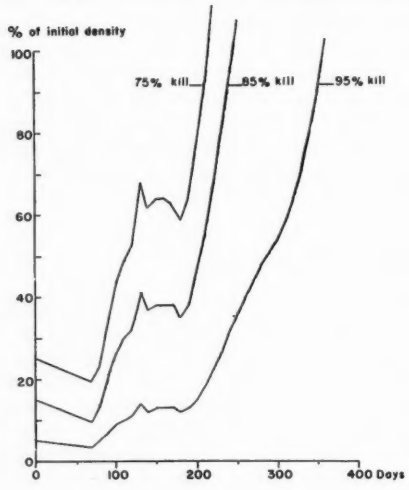
unsatisfactory for collecting young snails. In some instances, therefore, the team adopted the method of tube sampling, although this takes about ten times as long as the ring method. The tube, of the same diameter as the ring used for ring sampling, was pushed into the mud for a distance of 15-30 cm. In this way a plug of mud was obtained which was washed through a series of sieves of decreasing mesh sizes. This method yielded 32% more snails than the ring method when applied to the same site, and nearly all of them were less than 3 mm in length. The snails collected were fixed on cellulose tape and measured under a dissecting microscope fitted with an ocular micrometer.

The average densities of the colonies varied from 0.86 to 18.12 snails per ring sample. Statistical analysis of the results showed that there were highly significant differences not only between different colonies but also between the same colonies sampled at different times over a period of nearly two years. Furthermore, it could be shown that the density changes independently in different colonies and cannot therefore be due to a common cause, such as the weather.

Repopulation of snail colonies

It is obvious that any method of snail control that does not produce permanent changes in the habitat will have to be repeated at fairly frequent intervals if repopulation is to be prevented. It is therefore important to know how long a given percentage of survivors will take to restore a colony to its former density. The average adult life of female snails had already been determined, as well as the rate of egg-laying, the rate of survival and the time required from egg-laying to maturity. From these data it was possible to calculate repopulation curves for different rates of killing. In making these calculations it was assumed that the survival rates under the conditions of low population density prevailing shortly after control measures would be 50% better than those that had been determined under normal conditions. The fact that the survival rate would decrease

FIG. 5.
REPOPULATION CURVES OF *O. QUADRASI*



again as the population density neared its initial value was ignored, since control measures would in practice have to be reintroduced long before this point was reached. The calculated recovery rates for 75%, 85% and 95% kills are shown graphically in Fig. 5. The waves reflect succeeding generations of snails—a consequence of assuming that only adults survive. The curve for an initial kill of 85% agrees well with the average observed recovery rate of *O. quadrasi* colonies in Sorsogon province following molluscicidal operations estimated to have killed between 80% and 90% of the collectable snails.

From the repopulation curves it can be deduced that in order to maintain the population density below 20-30% of its normal value, it would be necessary to repeat molluscicidal treatment at intervals of about 120 days. The team concludes that a more economic approach would be to effect a radical alteration in the habitat, so as to reduce the rate of breeding to the point where the colony would eventually die out. They add: " If the land thus changed could then be put into agricultural production, the

repeated disturbance of farming might well hasten the disappearance of snails and further reduce the cost of maintenance."

Shedding of cercariae by infected snails

It had previously been reported that the shedding of cercariae by infected snails kept in the laboratory is cyclic in nature. Using a millipore-filtering apparatus, the team was able to make counts of the number of cercariae per 0.1 m^2 on the surface of the water in a natural snail habitat. Observations at four-hourly intervals showed a peak density at 11.00 p.m. at one site and at 7.00 p.m. at another. At both sites the minimum concentration was observed at 3.00 p.m. Repetition of the experiment at a later date, when the snail infection rate had decreased considerably, showed that although the average cercarial density was correspondingly lower, the peak period remained unchanged. Evidence was also obtained on another occasion that rainfall stimulates the shedding of cercariae. The risk of contracting infection from snail-infested waters is therefore greatest in the evening and particularly after rain.

When planning bilharziasis control measures it is important to know how far the cercariae can travel downstream away from the snail colonies. Tests carried out by the team indicated that, at a site in the Malirong river 150 m downstream from the nearest snail colony, the concentration of cercariae was almost as great as in the colony itself, at least in midstream. More surprising still, a pair of flukes were recovered from a mouse that had been placed in a floating cage in the Palo river at a point separated from the nearest colony by a waterfall 1.5 m high and by a kilometre of moderately flowing river. It is likely that the cercariae were released by an infected snail that had been carried downstream, but the team concluded that no fresh water downstream from any snail colony can ever be considered safe.

Snail control

The theoretically most effective way of attacking the problem of bilharziasis is to eliminate the colonies of vector snails, or at least to keep them in check. Methods of achieving this can be broadly divided into chemical and physical. Chemical methods—the use of molluscicides—are most suitable for clearing up small pockets of snails that remain after the main campaign has been completed. Physical methods—drainage, clearance of vegetation, etc.—are expensive, but they can be made to yield other benefits as well, such as the reclamation of swampy land and increased crop yields due to better farming methods. These were the main considerations that guided the team in its search for economic methods of control that would be suitable for application in Leyte.

Two experiments were conducted on the value of removing vegetation. The first snail colony selected was on the banks of a stream 260 m long and 1.2 m in average width. The bed of the stream and about 5 m on either bank were cleared of vegetation for lengths of 30-40 m. Alternate lengths were left uncleared as controls. A 34% reduction in the snail population was achieved in the cleared areas, whereas the uncleared areas showed an over-all increase in snail density. However, maintenance clearing had to be carried out five times during the nine months of the operation, a serious disadvantage of this method. The results were nevertheless considered sufficiently encouraging for the team to try a more thorough clearance experiment on a larger scale. The Binangkawan stream, a tributary of the River Palo, was cleared for its entire length of 426 m. In addition to cutting the vegetation, many roots were removed; the stream was also channelled and its banks were made vertical to render them less attractive to the snails. This procedure resulted in a reduction of 48% in the snail population. During the first 8 months, the vegetation was removed twice and control was satisfactorily maintained. For the next 8 months the stream was left untended and the population returned to its original density, but there was a renewed fall when a third maintenance clearing was carried out.

An adjacent snail colony in the Kanbanwa valley was considered to be a suitable area for an experiment in drainage. The colony

covered an area of about 7 hectares, made up of abandoned rice-fields and deeply waterlogged meadows. The vegetation was exuberant. From the head of the valley down to the Palo river there was a gradient of 1 in 300 (0.36%). Two canals were cut, joining up at the bottom of the valley to flow into the river. A few months later, the valley was completely dry and a noticeable change had occurred in the vegetation. Reduction in the snail colony began two months after completion of the canals, and after 10 months the snail density had fallen to less than 7% of what it had been initially. Nearly all the snails remaining were adults, showing that breeding had been interrupted. At the same time the land had been made suitable for farming. Maintenance of such drainage canals can be very expensive, however, if they are dug in sandy materials that have a tendency to cave in. Moreover, the canals must be kept clear of weeds as they might otherwise become suitable breeding grounds for the local malaria vector.

The effects of combined clearance and drainage were tested in the Magdalena swamps, in another part of the Kanbanwa valley. These were formerly covered about a metre deep with mud and overgrown with jungle and floating grasses. The clearing operations were started first and reduced the snail population to 41% of its original size. Subsequent drainage brought about a further reduction to only 4% of the original numbers, and in one area no snails have been found for 8 months.

An excessive amount of water can be as detrimental to snails as lack of water. Flooding of a small habitat reduced the snail population to less than 4% of the original density. This suggested that digging a series of ponds might also make an area uninhabitable for snails. An experimental pond, 8 m by 28 m and 2 m deep, proved very successful, and 8 months after its construction no snails could be found. The pond was constructed with vertical sides, but this can only be done in suitable soils. The method is expensive, but is useful where there are sluggish streams. The earth removed in digging can be used to fill in portions of the stream bed to make farming plots, and the ponds can afterwards be used for fish culture.

Snails and rice farming

Rice farming is one of the principal occupations of Leyte, rice being a staple of the diet. In fact, rice-fields constitute half the snail-infested area of Palo. Surveys made in Leyte at the end of the war had suggested that only few snails are found in the fields and that these are washed in from surrounding uncultivated areas, but the team found that this was not generally true. Many of the rice-fields are permanently waterlogged and support large populations of snails. The system of agriculture is very primitive. The land is not drained or dyked, and before planting the weeds are simply trampled into the mud by teams of water buffalo. Seedlings are planted haphazardly and the fields given no further attention until the harvest. The team designed a series of experiments to test whether improved farming would reduce or eliminate the snail populations.

In one experiment, traditional farming methods were compared with three different improved methods: ploughing and harrowing followed by traditional planting; traditional preparation followed by regularly spaced planting and weeding; and complete cultivation without dyking. A comparison was also made with land left unfarmed, giving five different treatments in all. Each of the treatments was applied to five plots, making a total of twenty-five plots. These were arranged in the form of a Latin square, i.e., so that no two plots in any one row or column received the same treatment. This arrangement eliminates errors due to chance differences between plots.

A parallel experiment was designed to test the effects of dyking on complete cultivation (ploughing, harrowing, spaced planting, weeding and sickling) and on traditional farming. A random arrangement of the plots was used for this experiment. The results clearly showed that each of the improvements (ploughing and harrowing; spaced planting, with weeding and sickling; and dyking) brought about marked reductions in snail

density, but they failed to provide evidence of a combined effect. This was not true, however, of the rice yields. Ploughing and harrowing alone gave no better yield than traditional farming, but when combined with proper spacing of seedlings and weeding they produced a 70% improvement in yield.

Sampling was difficult in these experiments since the snails tended to collect around the rice stalks. A further experiment was designed to overcome this difficulty by use of a special sampling technique, and at the same time some deficiencies in the farming methods were remedied. The experiment was conducted jointly by the bilharziasis control project and the Bureau of Agricultural Extension, and a graduate of the local agricultural school was employed to supervise the work. Only two types of farming were compared: complete cultivation (Masagana system) and traditional farming. Three plots were farmed by each method and three more left unfarmed as controls. The plots were again arranged in a Latin square. Before ploughing commenced, all plots, including controls, were surrounded by dykes. The snail density in the Masagana plots dropped to 1.4% of the initial value after the first weeding and recovered to 10.6% after harvesting. After traditional farming there was a drop to 10.2% of the original density, followed by recovery to 82.1%. The control plots showed little change—an increase of 4% was followed by a fall to 86% of the initial snail density. The differences in rice yields were striking. The Masagana plots gave an average yield that was nearly double that obtained by the routine method and almost three times the average for the province. It is clear, therefore, that the farmer who adopts improved agricultural methods will be amply compensated for the increased work involved and, at the same time, he will largely rid his fields of vector snails.

Environmental sanitation

In an attempt to assess the effectiveness of sanitation in interrupting the transmission of bilharziasis, a campaign of latrine construction was undertaken in the barrio of Malirong, one of the hyperendemic areas of Palo. Although no financial or material help was at first available, it was possible to persuade 119 of the 142 families to erect their own pit latrines. Unfortunately many of them were of such poor design and construction that they were blown down by a storm five months later. Nevertheless, snail colonies near the houses did show some reduction in infection rates shortly after the latrines were first put up.

This experiment could scarcely be considered a fair trial of the value of sanitation. The Philippine Government therefore consented to provide the materials necessary for the construction of a good latrine for every family in Malirong. This programme took nine months to complete, and during this time no effect on snail infection rates was observed. It may be that results could not be expected so quickly, but there is no doubt that the people are reluctant to use the latrines provided. Being unconvinced by the germ theory of disease, they do not find the pit latrine a superior method of faeces disposal. When defecation is done in the open, pigs quickly find and eat the faeces and there is therefore little smell. The latrines give off foul odours and at the same time deprive the pigs of an important source of food. It is hoped, however, that the people can be gradually educated to use the latrines, and monthly checks are being made to establish the extent to which success is being achieved. This experience underlines the importance of team-work in programmes of this kind: the sanitary engineer, the health educator, and the municipal health officer must work in close collaboration, and the provision of improved sanitary facilities should form only one part of a more comprehensive scheme of community development aimed at raising the living standards of the population.

The balance

The general conclusion to be drawn from this extensive survey is that bilharziasis in the Philippines is not an isolated medical problem but one that is closely bound up

with local agricultural practices. It is striking that the team's recommendations for keeping down the snail populations of the rice fields agree in every detail with the proposals made by the Bureau of Agricultural Extension for stepping up rice production—and it has been shown that they are capable of doubling the annual yield of rice. But there are many areas harbouring snails that are at present unsuitable for rice growing. Depending upon whether these are swamps, streams, or road ditches, they call for different methods of treatment, all of which are costly. Experience has shown, however, that the more radical the change in the habitat the greater is the reduction in snail density and the less the subsequent cost of maintenance. Half-measures are therefore likely to prove false economy. Moreover, the reclamation of wastelands and improved land utilization may be expected to yield in the long run much greater returns than the initial outlay.

A large-scale test of the effectiveness of environmental control in reducing the prevalence of bilharziasis has been started in the Palo area. The work is being co-ordinated with that of other agencies and gradually integrated into the over-all plan for the development of the province. It is expected to take about three years before a proper assessment can be made of the results. By then it should be possible to arrive at a much more accurate figure for the cost per head than is possible at present, and to decide to what extent auxiliary methods of control are necessary.

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JOINT OIHP/WHO STUDY-GROUP ON BILHARZIASIS IN AFRICA
Report on the first session. 1950. 16 p. (*Wld Hlth Org. techn. Rep. Ser.*, No. 17)

EXPERT COMMITTEE ON BILHARZIASIS
First report. 1953. 45 p. (*Wld Hlth Org. techn. Rep. Ser.*, No. 65)

STUDY-GROUP ON BILHARZIA SNAIL VECTOR IDENTIFICATION AND CLASSIFICATION
Bilharzia snail vector identification and classification (Equatorial and South Africa). Report of a study-group. 1954. 22 p. (*Wld Hlth Org. techn. Rep. Ser.*, No. 90)

EXPERT COMMITTEE ON INSECTICIDES
Specifications for pesticides. Insecticides, rodenticides, molluscicides and spraying and dusting apparatus. 1956. 400 p.

STUDY GROUP ON THE ECOLOGY OF INTERMEDIATE SNAIL HOSTS OF BILHARZIASIS
Report. 1957. 38 p. (*Wld Hlth Org. techn. Rep. Ser.*, No. 120)

AFRICAN CONFERENCE ON BILHARZIASIS
Report. 1957. 42 p. (*Wld Hlth Org. techn. Rep. Ser.*, No. 139)

Notes and News

About the *WHO Chronicle*

In the early days of WHO, its Interim Commission decided that a periodical was needed to give a month-by-month account of the Organization's activities, as well as short and readable accounts of work reported in other WHO publications, for the benefit primarily of the different health professions. This periodical first appeared in 1947 with the title *Chronicle of the World Health Organization*, and has been issued regularly ever since. The 4300 pages so far published contain a record of what has happened throughout the world in the field of international health since January 1947.

This, the 145th issue, appears with a new title and a new face. The *Chronicle of the World Health Organization* is now the *WHO Chronicle*. The new, briefer title simplifies acknowledgements and references, and some medical journals have in fact been using it lately in preference to the longer one. This hint has accordingly been taken.

Small as the change of title appears to be, it has a significance which may not be immediately obvious. Twelve years ago, the new title was one of those considered for WHO's new periodical. It was rejected, on the then unchallengeable ground that only a few could be expected to know the meaning of the initials " WHO ".

The change in the Chronicle does not go deeper than its cover. Content, editorial policy, and presentation remain unaltered, in accordance, it seems, with the wish of most of its readers.

Since the Chronicle was first published, three attempts have been made to establish contact with its readers and to learn to what extent it was being found useful or could be improved.

A questionnaire was widely circulated among the technical staff of the Organization in 1951, and another sent in 1953 to several hundred former WHO Fellows. Although, as was to be expected, many of the suggestions received in answer were impracticable, and some of the criticisms were based on an inadequate understanding of the role and scope of the Chronicle as defined by the WHO governing bodies, these contacts with two entirely different groups of readers did result in some constructive criticism. As a consequence, a number of adjustments were gradually made, both in the content and in the presentation.

A third attempt to sound the views of readers was made in 1957 on a smaller, but more selective, scale. With the help of the secretaries of WHO Expert Advisory Panels, a few members were selected from each panel and the questionnaire was sent to them. In this manner approximately 100 outstanding experts in various fields were approached.

Comments were invited on nine specific points. Two questions were of special interest: one asking for an opinion on the general usefulness of the periodical; the other dealing with a fundamental aspect of editorial policy, i.e., whether or not Chronicle articles should be signed.

The answer to the first question—whether the Chronicle was a useful periodical—was overwhelmingly in the affirmative. With the exception of a handful of correspondents whose interests were too specialized for them to find the Chronicle of direct use, all those approached stated that they read the Chronicle regularly and found it the best way of keeping informed on WHO's work and on international developments in public health in general. Most readers thought that the Chronicle contained a great deal of useful information in concentrated form, and a comment frequently made or implied was

that to the specialist reader the Chronicle was welcome because of its articles on subjects other than his own. Some correspondents used the Chronicle as teaching material; others used it in their capacity as authors or editors of journals; and the point was made that librarians found it valuable as a permanent source of reference to the work of WHO and a guide to its other publications. One of the views most frequently expressed might be put thus: "It provides me with a broad survey of health problems throughout the world, and shows how WHO is helping to solve them", and some correspondents stressed that they knew of no other source where they could find such information. Analysis of the replies shows that an overwhelming majority wished the Chronicle to continue and felt that it should not undergo any major changes.

While all readers seemed to understand what the Chronicle is, some failed to see what the Chronicle cannot be. This appeared clearly from some of the replies to the questionnaire.

One reader wanted the Chronicle "to bring regular news, arranged by countries, from the ministries competent for the different fields of public health, from scientific institutions, technical institutions, technical associations, and their leading and influential experts". He added that "this type of information is very difficult to get", but would be welcomed by "many experts in all countries". The same wish, in one form or another, has been expressed from time to time by other readers of the Chronicle. There may be need for information of this type, but it cannot be provided by the Chronicle within its present terms of reference, because such activities are not international. The information would be enormously difficult to obtain, and even more difficult, if not impossible, to check for accuracy. So one of the Chronicle's main objects—to offer fully reliable information—would be lost.

Another reader wanted "an occasional inclusion of a leading general article by a well-known authority on a topical subject, . . . [such as] chemical determination of heredity, present status of cancer research . . ." Here, again, it may be of interest to some readers to have articles of this type, but it is questionable whether a periodical which is, in a way, the mouthpiece for an intergovernmental organization, would be a logical vehicle for such material. The Chronicle regularly informs its readers of what is actually done in the field of international health. What yardstick could be used for the selection of problems which have not so far been dealt with by WHO ?

Yet another reader asked whether the Chronicle could not "publish up-to-date international reviews of medical publications, epidemiological and statistical information". This is an attractive idea, and seemed to enjoy a certain popularity. It was considered, along with many other possibilities, in the Chronicle's early days, but it was not found practicable. A private publisher enjoys complete freedom in the selection of publications for review and criticism. Not so a publication which appears under the imprint of an international organization representing 85 governments, and is therefore subject to limitations that must be recognized and accepted.

Opinion on the question of signed or anonymous articles appeared to be divided almost equally, and it is interesting to note that the majority of correspondents appeared to feel quite strongly one way or the other in this respect. Some supported the present policy of the Chronicle, which is to offer signed contributions only in exceptional cases. The arguments advanced were that unsigned contributions carried greater weight; that the names of many of the authors were bound to be known only to a small group of specialists, and so would add nothing to the value of the contributions; and that signed contributions belonged elsewhere—to the *Bulletin of the World Health Organization* if they were technical, to *World Health* if they were popular. Other correspondents favoured a departure from the present policy, and the more frequent inclusion of articles signed by consultants and members of Expert Committees. The arguments advanced here were that the kind of experience conveyed in signed contributions of this type could not be

found in anonymous articles; that a signed contribution enabled the reader to get in touch with the author; and that the reader is entitled to know the authority behind the text which he reads. But the main reason prompting these requests for more signed contributions seems to be personal aversion to anonymous texts, which is probably to some extent a reflection of differing practices in various parts of the world.

* * *

In a Foreword published in the first number of the Chronicle of the World Health Organization, the point was made that " the funds which pay for these [international health] activities come ultimately from the pockets of millions of taxpayers and it is proper that any who are interested should know on what this money is spent ". For twelve years the *Chronicle of the World Health Organization* has attempted to do this, to carry out soberly its allotted task of informing the reader about the activities of WHO. The *WHO Chronicle* will continue to follow this path in the years to come.

The efficacy of smallpox vaccines

The efficacy of a preparation of smallpox vaccine can ultimately only be proved by its ability to protect against the disease. But it is considered highly probable that a vaccine is protective if it elicits a primary vesicular response in the unvaccinated, followed by resistance to subsequent vaccination with a potent vaccine lymph.

Dried and glycerinated vaccines were compared by these criteria in a recent experiment in England.[1] Both types of vaccine produced 100% vesiculations in primary vaccinations of groups of volunteers, and equal resistance to revaccination with a potent lymph one year later. In a parallel experiment the potencies of the same vaccines were reduced by exposure to heat to a point where less then 50% successful primary vaccinations were obtained. All those, however, that responded with a primary vesiculation to any of the vaccines used were equally resistant, one year later, to revaccination with a potent vaccine lymph. The results indicate that dried smallpox vaccines confer satisfactory protection, and that the immune states following successful vaccination with vaccines of low potency and of normal potency cannot be distinguished.

A parasitological problem solved

The parasites of filariasis spend part of their life cycle in mosquitos and other blood-sucking insects. The parasitologist investigat ing the extent of infection in mosquitos, the species of larvae causing the infection, and the stage of their development within the mosquitos is faced with the problem of preserving the mosquitos long enough to be able to dissect them and carry out his observations accurately. A simple method of preserving the mosquitos and staining the filarial larvae before dissection has been developed in Kenya, and is reported on in a recent number of the WHO Bulletin (*Bull. Wld Hlth Org.*, 1958, **19**, 205).

Lung cancer

The fact that the classification and nomenclature of cancer tumours vary from one country to another, and even within individual countries, makes it difficult to attack the problem of cancer on an international scale. On the recommendation of the Study Group on Histological Definitions of Cancer Types, which met in Oslo in 1957, WHO has decided to encourage the establishment of international centres which, in collaboration with certain specialized institutions, will study the histological definitions of different types of tumour and seek a universally acceptable classification and nomenclature.

As a first step in this direction, an international centre for lung cancer has been set up at the Institute for General and Experimental Pathology in Oslo, under the direction of Professor L. Kreyberg. A WHO Expert

[1] *Bull. Wld Hlth Org.*, 1958, **19**, 123

Committee on Histopathology met at this centre, from 17 to 22 November 1958, to study the classification and nomenclature of tumours of the lung and propose a working programme for the centre and groups associated with it. The members of the Expert Committee were: Professor J. Delarue (France), Professor H. Hamperl (Germany), Professor L. Kreyberg (Norway), Professor A. Liebow (USA), Professor R. Scarff (United Kingdom), and Professor E. Uehlinger (Switzerland). Dr R. Sansonnens (WHO) was Secretary to the Committee.

International Pharmacopoeia : specifications for reagents

The World Health Organization proposes to publish a volume containing specifications for the reagents required in connexion with the tests described in Volumes I and II and the Supplement of the International Pharmacopoeia. Draft specifications have been prepared with the advice of members of the Expert Advisory Panel on the International Pharmacopeia and Pharmaceutical Preparations.

A tentative list of these reagents will be supplied on request. Comments on the draft specifications are invited, and copies of the drafts may be obtained for this purpose from the Secretary, Expert Advisory Panel on the International Pharmacopoeia and Pharmaceutical Preparations, World Health Organization, Palais des Nations, Geneva.

Expert Committee on the International Pharmacopoeia

Although a Supplement dealing with a series of new pharmaceuticals is to be added to the present edition of the International Pharmacopoeia, it has been felt that a second and enlarged edition, based on revised analytical methods, would be desirable. The preparation of this new edition was the principal subject discussed by the WHO Expert Committee on the International Pharmacopoeia, which met in Geneva from 10 to 15 November 1958.

The Committee also reviewed reactions to the proposal that WHO should issue information sheets on new pharmaceutical preparations to assist Pharmacopoeia Commissions and national Health Administrations in the early control of the quality of new drugs and of their pharmaceutical forms. This idea had been generally welcomed by national drug control administrations and it was necessary to obtain the support of the pharmaceutical industry, which would be called upon to supply much of the information required.

A report on the activities of the Centre for Authentic Chemical Substances in Stockholm was examined. The possibility of keeping, at this Centre, a number of chemical substances to serve as melting-point reference standards and for checking spectrophotometers was considered.

In accordance with a resolution adopted at the XVIIth General Assembly of the International Pharmaceutical Federation and in response to requests from several countries, the Committee also discussed the principles which could be followed in different countries in preparing lists of pharmaceutical substances and specialities to be sold on prescription.

The following experts were invited to attend the Expert Committee's session: Professor H. Baggesgaard Rasmussen (Denmark); Professor A. Calò (Italy); Dr T. Canbäck (Sweden), Chairman; Mr. T. C. Denston (United Kingdom), Rapporteur; Professor J. A. Gautier (France); Dr P. H. List (Germany); Dr L. C. Miller (USA), Rapporteur; Professor P. Senov (USSR); and Professor C. Suvagondha (Thailand), Vice-Chairman. The consultants to the Expert Committee were Mr G. R. Brown (United Kingdom), Professor H. Flück (Switzerland), and Professor R. Hazard (France). Mr P. Blanc (WHO) acted as Secretary to the Committee.

Hospital statistics and their application

With the rapid increase of hospital services throughout Europe, there is a corresponding need for the proper evaluation of the medical, administrative and other aspects of their work. In this connexion, hospital statistics

can be extremely helpful to the health administrator.

A Conference on Hospital Statistics and their Application in Health Administration, sponsored by the WHO Regional Office for Europe, met in Geneva from 24 to 28 November 1958. It was attended by health administrators and statisticians from Austria, Belgium, Czechoslovakia, Germany, Greece, Ireland, Italy, the Netherlands, Poland and Yugoslavia. The participants reviewed the present status of hospital statistics in Europe and discussed the problems involved in their future development, with special emphasis on their use in the evaluation and planning of hospital services.

New pamphlet on WHO

A 20-page pamphlet entitled *The World Health Organization—Its Global Battle against Disease* was recently published by the Public Affairs Committee of New York, an educational organization founded in 1935 "to develop new techniques to educate the American public on vital social and economic problems and to issue concise and interesting pamphlets dealing with such problems, derived wherever possible from the long-time studies of leading research institutions".

The pamphlet on WHO was prepared by Mr Albert Deutsch, a well-known writer on health and welfare subjects, to commemorate the Organization's tenth anniversary, and has a preface by Dr Charles W. Mayo, of the Mayo Clinic, Rochester, Minn. It costs $0.25, and can be obtained from Public Affairs Pamphlets, 22 East 38th Street, New York 16, N.Y., USA.

Appointment of a new Assistant Director-General

Dr Nicolay Ivanovich Grashchenkov, of the USSR, has been appointed Assistant Director-General of WHO to replace Dr W. A. Timmerman who recently retired.

Born in the Smolensk region in 1901, Dr Grashchenkov is a graduate of the Medical Faculty of the University of Moscow. In 1938 he was appointed to the Chair of Neurology at the first Moscow Medical Institute, and in 1955 he became Chairman of the Medical Research Council of the USSR Ministry of Health. He has been a member of scientific missions to England and the United States, and a delegate to the last two World Health Assemblies.

In his position as one of the three Assistant Directors-General of WHO, Dr Grashchenkov will advise the Director-General on major questions of policy, and will be responsible for technical aspects of liaison with the regional offices and other agencies.

Organizational changes at WHO Headquarters

The Director-General of WHO has decided to make several organizational changes at WHO Headquarters so as to adapt the Secretariat to developments which have taken place in the Organization's work over the past few years.

Division of Epidemiological and Health Statistical Services

The Division of Epidemiological and Health Statistical Services has been renamed the Division of Health Statistics with effect from 1 January 1959. International Quarantine has been transferred to the Division of Communicable-Disease Services, and the remaining sections have been converted and renamed as follows: Health Statistical Methodology (formerly Statistical Studies); Consolidation of Health Statistics (formerly Epidemiological Studies); International Classification of Diseases and Development of Health Statistical Services (formerly International Classification of Diseases and Causes of Death).

Division of Therapeutic Substances

The Division of Therapeutic Substances has been renamed the Division of Biology and Pharmacology with effect from 1 January 1959. In addition to the Office of the Director, it now includes: Radiation and Isotopes (formerly Atomic Energy in Relation to Health, in the Office of the Director-General);

Biological Standardization; Pharmaceuticals; Addiction-Producing Drugs.

Health Laboratory Methods has been transferred to the Division of Organization of Public-Health Services, and its title has been changed to Health Laboratory Services.

Division of Organization of Public-Health Services

Two new units of activity—namely, Cardiovascular Diseases, and Cancer—have been created in the Division of Organization of Public-Health Services, with effect from 1 November 1958.

Division of Communicable-Disease Services

One new unit of activity—namely, Leprosy—has been created in the Division of Communicable-Disease Services, with effect from 1 November 1958.

With effect from 1 December 1958, the Departments of Advisory Services, Central Technical Services, and Administration and Finance have been abolished. From that date, each Assistant Director-General has been responsible for directing the activities of certain divisions and offices as assigned by the Director-General. Thus, Dr P. M. Kaul is in charge of the Divisions of Communicable Diseases, Organization of Public-Health Services, Education and Training, Environmental Sanitation, and Malaria Eradication, as well as the Offices of Programme Co-ordination and Programme Evaluation. Dr N. I. Grashchenkov is responsible for the Divisions of Health Statistics, Biology and Pharmacology, and Editorial and Reference Services, and Mr M. P. Siegel for the Division of Administrative Management and Personnel, the Division of Budget and Finance, the Legal Office, and the Office of Internal Audit.

Review of WHO Publications

TUBERCULIN

Bulletin of the World Health Organization, Volume 19, Number 5 (pages 759-952)

Variation in tuberculin potency is the main theme of the papers in this issue of the Bulletin, which is concerned with the production, dilution, stabilization and storage of the purified tuberculin (PPD) used in BCG campaigns and other projects sponsored by UNICEF and WHO. This collection of papers has been prepared by the WHO Tuberculosis Research Office and the Statens Seruminstitut, Copenhagen.

The first three papers deal with the stability of PPD when diluted as for use in intradermal testing, that is, in the ratio 1/1 000 000 or thereabouts. The first paper is concerned with long-term storage, and demonstrates that, in the main, tuberculin dilutions are surprisingly stable; it is concluded that tuberculin in diluted form, ready for use, may be distributed in simpler and less expensive ways than hitherto often used.

The data from these studies of storage do, however, show unpredictable variations in potency between dilutions prepared in the same way from the same stock solution, and even differences in potency between ampoules filled with tuberculin dilution from the same container. These variations are further examined in the second paper, together with another manifestation of instability observed by the authors—namely, that a tuberculin dilution kept in a bottle or ampoule which is only partially filled loses most of its potency (per unit volume) relative to a similar dilution kept in a bottle which is completely filled. Evidence is offered that these phenomena are

solely due to adsorption to the glass walls of bottles and ampoules of more than half of the diluted tuberculin, sometimes much more than half, so that it is not surprising if the small amount of unadsorbed tuberculin varies from ampoule to ampoule.

The third of the papers gives further information on the dependence of the adsorption on the diluent used. That tuberculin diluted in saline is weaker than tuberculin diluted in buffer has been known for a long time, but this effect is now seen to be due to increased adsorption. The adsorption may be further inhibited by the use of other additives besides buffer salts; proteins such as blood albumin or gelatine reduce the adsorption considerably, but of all the additives tested so far, the non-ionic detergent " Tween 80 " gives the strongest and most constant stability. The authors suggest that Tween 80 (in a concentration of 0.05‰) be used as a matter of routine in the future as additive to the tuberculin diluent, so as to prevent unpredictable variations in the potency of the dilutions.

The next two papers are concerned with a new, very large batch of tuberculin recently produced in the Statens Seruminstitut, Copenhagen, at the request of UNICEF. First, the preparation of this batch is described. Cultures of tubercle bacilli on a synthetic medium were subjected to heat treatment, sterilè filtration, ultrafiltration, and precipitation with trichloracetic acid, and the precipitate was dehydrated with ether. Seven different strains of human type tubercle bacilli were used and several sub-batches made from each. After the sub-batches had been found to be fairly uniform in potency, by testing in guinea-pigs, they were pooled and thoroughly mixed. The total lot came to 670 grams and is tentatively designated RT 23.

The new tuberculin was standardized in human populations in the Netherlands, Nigeria, Mauritius and Denmark, as well as in guinea-pigs sensitized in several ways. The standardization included not only a comparison with the International Standard for the Purified Protein Derivative of Mammalian Tuberculin (PPD-S), but also with the earlier products from the Statens Seruminstitut, RT 19-20-21 and RT 22. For RT 23 both buffer diluent with Tween 80 and buffer diluent without Tween 80 were used. For the other tuberculins only buffer diluent without Tween 80 was used.

The comparisons, which are reported in the final paper, gave very definite evidence of " qualitative " differences between the tuberculin products, so that no single, absolute standardization is possible. In the light of the results in naturally infected humans, in terms of reaction size, it is suggested that the following doses be considered equipotent for practical purposes:

0.000084 mg (including 0.000024 mg of buffer salts) of the International Standard (3 TU)
0.0001 mg of RT 19-20-21 (" 5 TU")
0.00009 mg of RT 22 (" 7 TU ")
0.00006 mg of RT 23 without Tween 80
0.00002 mg of RT 23 with Tween 80

To keep in agreement with the terminology of the existing definition of the International Tuberculin Unit, it seems necessary to define one unit of RT 23 in terms of dry weight and irrespective of the diluent used. As 0.00006 mg of RT 23 (diluted without Tween) corresponds to 3 TU of the International Standard (diluted without Tween), one unit of RT 23 thus becomes 0.00002 mg of the dry substance. This means that the dilution of RT 23 with Tween 80 which may substitute " 5 TU " of RT 19-20-21 must be labelled " one tuberculin unit ". This is regretted by the authors as it will no doubt cause some confusion.

If 0.00002 mg of RT 23 stabilized with Tween 80 is accepted as the future standard test, there is (neglecting losses) a total of 33 000 000 000 doses of 0.00002 mg each in the whole batch. Even if this is not enough to cover world requirements until the complete eradication of tuberculosis has been effected, it may last for a great many years, very likely until after it has been outmoded by new types of tuberculin, especially tuberculins with selected properties of specificity.

The list of contents will be found in the advertising section at the end of this number of the Chronicle.

Tenth Anniversary Commemorative Session held by the World Health Assembly at Minneapolis, 26-28 May 1958, Geneva, 1958 (*Off. Rec. Wld Hlth Org.* No. 86), 81 pages. Price: 3/6, $0.70 or Sw. fr. 2.—. Also published in French and Spanish.

A special session of the World Health Assembly was held at Minneapolis, Minnesota, USA, from 26 to 28 May 1958, to commemorate the tenth anniversary of the World Health Organization.

This volume contains the full verbatim records of the proceedings, a summary of which has already appeared in the Chronicle.[1]

[1] *Chron. Wld Hlth Org.*, 1958, **12**, 219

ADDENDUM

Vol. 12, No. 10

DENTAL HEALTH SERVICES FOR CHILDREN

Page 341, footnote (list of participants)
add Dr W. Kessler (Federal Republic of Germany)

TUBERCULIN

Introduction

Stability of purified tuberculin in high dilution—*Knut Magnus, Johannes Guld, Hans Waaler & Mogens Magnusson*

Adsorption of tuberculin to glass—*Hans Waaler, Johannes Guld, Knut Magnus & Mogens Magnusson*

Diluents for stabilization of tuberculin—*Mogens Magnusson, Johannes Guld, Knut Magnus & Hans Waaler*

Preparation of purified tuberculin RT 23—*Mogens Magnusson & M. Weis Bentzon*

Standardization of a new batch of purified tuberculin (PPD) intended for international use—*Johannes Guld, M. Weis Bentzon, M. A. Bleiker, W. A. Griep, Mogens Magnusson & Hans Waaler*

BULLETIN OF THE WORLD HEALTH ORGANIZATION

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